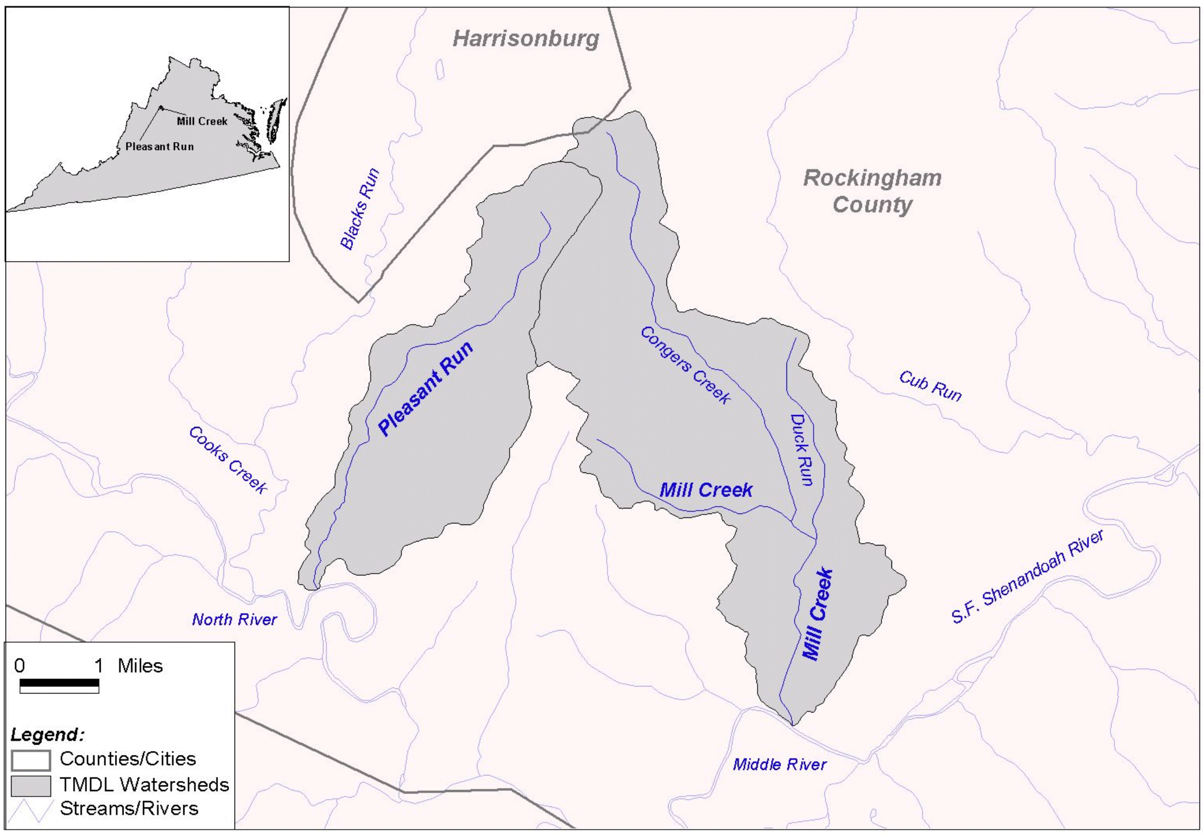
Total Maximum Daily Load (TMDL) Development for Mill Creek and Pleasant Run (Rockingham County, Virginia)

Aquatic Life Use (Benthic) Impairment



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Background

Mill Creek and Pleasant Run are located in Rockingham County, Virginia, in the South Fork Shenandoah River basin (USGS Hydrologic Unit Code, 02070005). Both streams eventually flow into the Potomac River, which is a tributary to the Chesapeake Bay. The waterbody identification codes (WBID, Virginia Hydrologic Unit) for Mill Creek and Pleasant Run are VAV-B29R and VAV-B27R, respectively (VADEQ 1998).

Virginia 305(b)/303(d) guidance states that support of the aquatic life beneficial use is determined by the assessment of conventional pollutants (dissolved oxygen, pH, and temperature); toxic pollutants in the water column, fish tissue and sediments; and biological evaluation of benthic community data (VADEQ 2002). Benthic community assessments are, therefore, used to determine compliance with the General Criteria section of Virginia's Water Quality Standards (9 VAC 25-260-20). In general, the stream reach that a biomonitoring station represents is classified as impaired if the EPA's Rapid Bioassessment Protocol (RBP) ranking is either moderately or severely impaired. According to Virginia's 1998 303(d) list, the biological monitoring station on Mill Creek indicated moderate impairment and the biological monitoring station on Pleasant Run indicated severe impairment of the benthic community. As a result, these streams were listed as impaired due to violations of the general standard (aquatic life) on the 1998 303(d) list. The impairment listing for these streams remained the same in the 2000 305(b) assessment.

Water quality data analyses and field observations indicate that the primary causes of the benthic community impairment in these streams are increased amounts of sediment and phosphorus. In order to improve water quality conditions that have resulted in the listed benthic impairments, Total Maximum Daily Loads (TMDLs) were developed for each impaired watershed, taking into account all sources of sediment and phosphorus, plus a margin of safety (MOS). Upon implementation, the TMDLs will ensure that water quality conditions relating to benthic impairment will meet the allowable loadings estimated by use of a reference watershed (a non-impaired watershed with characteristics similar to those of the impaired watersheds).

Sources of Sediment and Phosphorus

Sediment and phosphorus sources can be divided into point and nonpoint sources. There are three minor point sources of sediment and phosphorus in the Mill Creek watershed and none in the Pleasant Run watershed. Point sources in the Mill Creek watershed were issued VPDES domestic sewage discharge general permits. These facilities discharge less than 1,000 gallons per day (Table 1).

Table 1. VPDES point source facilities in the impaired watersheds

Stream	Facility	VPDES Permit No.	Discharge Type	Design Flow (gpd)	Sediment Load (pounds/year)	Phosphorus Load (pounds/year)
Mill Creek	Single Family House - Route 1, Port Republic	VAG401620	SFH	<1,000	92	46
	Single Family House - Route 276	VAG401103	SFH	<1,000	92	46
	Mill Creek Church of the Brethren - 7600 Port Republic	VAG401465	Private	<1,000	92	46
Pleasant Run	N/A	N/A	N/A	N/A	N/A	N/A

Sediment and phosphorus loads in the impaired watersheds are primarily contributed by nonpoint sources. The major nonpoint sources of sediment and phosphorus in these watersheds are agricultural and urban lands. Agricultural and urban lands can contribute excessive sediment and phosphorus loads through erosion and build-up/washoff processes. Agricultural lands are particularly susceptible to erosion, which contributes sediment and adsorbed phosphorus loads. Phosphorus is also associated with the land-application of animal waste and failing septic systems.

Modeling

TMDLs were developed using BasinSim 1.0 and the GWLF model. GWLF is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values.

Daily streamflow data are needed to calibrate watershed hydrologic parameters in the GWLF model. For Mill Creek and Pleasant Run, only a few monthly observations of stream flow were available. USGS stream flow data from nearby Linville Creek were used to estimate daily flows for Mill Creek and Pleasant Run. Linville Creek flow data were corrected based on differences in watershed size. Considering that the Linville Creek watershed shares similar geomorphology, hydrology, and land use characteristics as Mill Creek and Pleasant Run, this method was deemed appropriate. The calibration period covered a wide range of hydrologic conditions, including low- and high-flow conditions as well as seasonal variations. The calibrated GWLF model adequately simulated the hydrology of the impaired watersheds.

TMDL development requires the identification of impairment causes and the establishment of numeric endpoints that will allow for the attainment of designated uses and water quality criteria. Numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. Virginia does not currently have numeric criteria for nutrients (i.e. total phosphorus and total nitrogen), sediment, and other parameters that may be contributing to the impaired condition of the benthic community in these streams. Therefore, a reference watershed approach was used to determine the primary benthic community stressors and to establish numeric endpoints for these stressors. This approach is based on selecting a non-impaired watershed that shares similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. Hays Creek was chosen as the reference watershed and any reductions of sediment and phosphorus from the impaired waterbodies was based on the reference loads of sediment and phosphorus in the Hays Creek watershed.

Existing Conditions

Impaired and reference watershed models were calibrated for hydrology using different modeling periods and weather input files. To establish baseline (reference watershed) loadings for sediment and phosphorus, the GWLF model for Hays Creek was run with the same weather input file that was used for the impaired watershed simulations. This step was needed to standardize the modeling period and weather conditions (which affect pollutant loading rates) between impaired and reference watersheds for the calculation of TMDLs. In addition, the total area for the reference watershed was reduced to be equal to its paired target watershed. This was necessary because watershed size influences sediment delivery to the stream and other model variables.

The six-year means for sediment and phosphorus were determined for each land use/source category in the Mill Creek and Pleasant Run watersheds.

Transport loss estimates were used to determine the total sediment and phosphorus loads contributed by the three VPDES point sources in the Mill Creek watershed (* there are no point sources in the Pleasant Run watershed). The sediment delivery ratio calculated for the Mill Creek watershed (16.26%) was used to estimate sediment and phosphorus transport losses caused by deposition, removal, and other in-stream processes.

Margin of Safety

While developing allocation scenarios for these TMDLs, an explicit margin of safety (MOS) of 10 percent was used. Ten percent of the reference sediment and phosphorus load was calculated and added to the sum of the load allocation (LA) and wasteload allocation (WLA) to produce the TMDL. It is assumed that a MOS of 10 percent will account for any uncertainty in the data and the computational methodology used for the analysis, as well as provide an additional level of protection for designated uses.

Allocation Scenarios

Load or wasteload allocations were assigned to each source category in the watersheds. Several allocation scenarios were developed for each watershed and pollutant to examine the outcome of various load reduction combinations. The recommended scenarios for Mill Creek (Table 2) and Pleasant Run (Table 3) are based on maintaining the existing percent load contribution from each source category. Two additional scenarios for each watershed and pollutant are presented for comparison purposes (Tables 4 and 5). Load reductions from agricultural sources are minimized in the first alternative and reductions from urban lands are minimized in the second alternative. The recommended scenarios balance the reductions from agricultural and urban sources by maintaining existing watershed loading characteristics. In each scenario, loadings from certain source categories were allocated according to their existing loads. For instance, sediment and phosphorus loads from forest lands represent the natural condition that would be expected to exist; therefore, the loading from forest lands was not reduced. Also, point source loads (Mill Creek watershed) were not reduced because these facilities are currently meeting the VPDES general permit requirements for small domestic sewage discharges. Current permit requirements are expected to result in attainment of the WLAs as required by the TMDL. Point source contributions even in terms of maximum flow are minimal, therefore, no reasonable potential exists for these facilities to have a negative impact on water quality and there is no reason to modify the existing permits.

Table 2. Recommended sediment and phosphorus allocations for Mill Creek (at the mouth)

Source Category	Sediment Load Allocation (lbs/yr)	Sediment - % Reduction	Phosphorus Load Allocation (lbs/yr)	Phosphorus - % Reduction
Row Crops	4,066,916	45%	2,072	67%
Pasture/Hay	1,934,817	45%	1,124	60%
Transitional	12,765	70%	14	50%
Forest	26,308	0%	18	0%
Water	0	0%	0	0%
Urban (grouped pervious & impervious areas)	229,892	37%	1,055	40%
Groundwater	0	0%	782	0%
Point Sources (WLA) * Existing load minus transport loss (see footnote)	231 (total) (WLA for each point source = 77)	0%	116 (total) (WLA for each point source = 38.7)	0%
Septic Systems	0	0%	219	50%
TMDL Load (minus MOS)	6,270,928		5,401	

Table 3. Recommended sediment and phosphorus allocations for Pleasant Run (at the mouth)

Source Category	Sediment Load Allocation (lbs/yr)	Sediment - % Reduction	Phosphorus Load Allocation (lbs/yr)	Phosphorus - % Reduction
Row Crops	3,007,955	70%	2,022	70%
Pasture/Hay	734,632	70%	542	70%
Barren	73,719	80%	47	80%
Forest	16,505	0%	11	0%
Water	0	0%	0	0%
Urban (grouped pervious & impervious areas)	137,297	70%	259	70%
Groundwater	0	0%	433	0%
Point Sources (WLA) (none in the watershed)	0	0%	0	0%
Septic Systems	0	0%	204	15%
TMDL Load (minus MOS)	3,970,108		3,519	

Table 4. Alternative sediment and phosphorus allocations for Mill Creek (at the mouth)

Source Category	Sediment		Phosphorus	
	Minimize Agricultural Reductions	Minimize Urban Reductions	Minimize Agricultural Reductions	Minimize Urban Reductions
Row Crops	44%	46%	57%	71%
Pasture/Hay	42%	45%	52%	69%
Transitional	90%	70%	80%	50%
Forest	0%	0%	0%	0%
Water	0%	0%	0%	0%
Urban (grouped pervious & impervious areas)	90%	10%	80%	10%
Groundwater	0%	0%	0%	0%
Point Sources (WLA)	0%	0%	0%	0%
Septic Systems	0%	0%	80%	50%

Table 5. Alternative sediment and phosphorus allocations for Pleasant Run (at the mouth)

Source Category	Sediment		Phosphorus	
	Minimize Agricultural Reductions	Minimize Urban Reductions	Minimize Agricultural Reductions	Minimize Urban Reductions
Row Crops	75%	78%	75%	80%
Pasture/Hay	50%	50%	50%	65%
Barren	80%	80%	75%	75%
Forest	0%	0%	0%	0%
Water	0%	0%	0%	0%
Urban (grouped pervious & impervious areas)	80%	10%	80%	10%
Groundwater	0%	0%	0%	0%
Point Sources (WLA)	0%	0%	0%	0%
Septic Systems	0%	0%	15%	15%

The TMDLs established for Mill Creek and Pleasant Run consist of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The sediment and phosphorus TMDLs for Mill Creek and Pleasant Run were based on the total load calculated for the Hays Creek watershed (area adjusted to the appropriate watershed size).

The TMDL equation is as follows:

TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis.

TMDLs for Mill Creek and Pleasant Run were calculated by adding reference watershed loads for each pollutant of concern together with point source loads to give the TMDL value (Table 6). Note that the sediment and phosphorus WLA values presented in the TMDL tables represent the sum of all point source WLAs in each watershed, minus in-stream transport loss (as described above).

Table 6. TMDLs for Mill Creek and Pleasant Run (at the mouth of each stream)

Watershed	Pollutant	TMDL (lbs/yr)	LA (lbs/yr)	WLA (lbs/yr)	MOS (lbs/yr)	Overall % Reduction
Mill Creek	Sediment	6,967,698	6,270,697	231(total) (WLA for each point source = 77)	696,770	45%
	Phosphorus	6,001	5,285	116 (total) (WLA for each point source = 38.7)	600	56%
Pleasant Run	Sediment	4,411,231	3,970,108	0	441,123	71%
	Phosphorus	3,910	3,519	0	391	66%

* *Note that the overall % reduction is applied to the TMDL load exclusive of the MOS.*

SECTION 1

INTRODUCTION

1.1 Background

1.1.1 TMDL Definition and Regulatory Information

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies which are exceeding water quality standards. TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and nonpoint sources to restore and maintain the quality of their water resources (USEPA 1991).

1.1.2 Impairment Listing

Mill Creek and Pleasant Run are listed as impaired on Virginia's 1998 Section 303(d) Total Maximum Daily Load Priority List and Report due to violations of the State's water quality standards for fecal coliform bacteria and violations of the General Standard (benthics) (VADEQ 1998). The Mill Creek segment begins at its headwaters and continues to its confluence with the North River (2.66 miles in length). The Pleasant Run segment also begins at its headwaters and ends at its confluence with the North River (6.3 miles in length). This report addresses the benthic community impairments on these streams. TMDLs for fecal coliform bacteria were previously developed by the Commonwealth of Virginia and EPA for these streams.

1.1.3 Watershed Location

Mill Creek and Pleasant Run are located in Rockingham County, Virginia, in the South Fork Shenandoah River basin (USGS Hydrologic Unit Code, 02070005) (Figure 1.1). Both streams eventually flow into the Potomac River, which is a tributary to the Chesapeake Bay. The waterbody identification codes (WBID, Virginia Hydrologic Unit) for Mill Creek and Pleasant Run are VAV-B29R and VAV-B27R, respectively (VADEQ 1998).

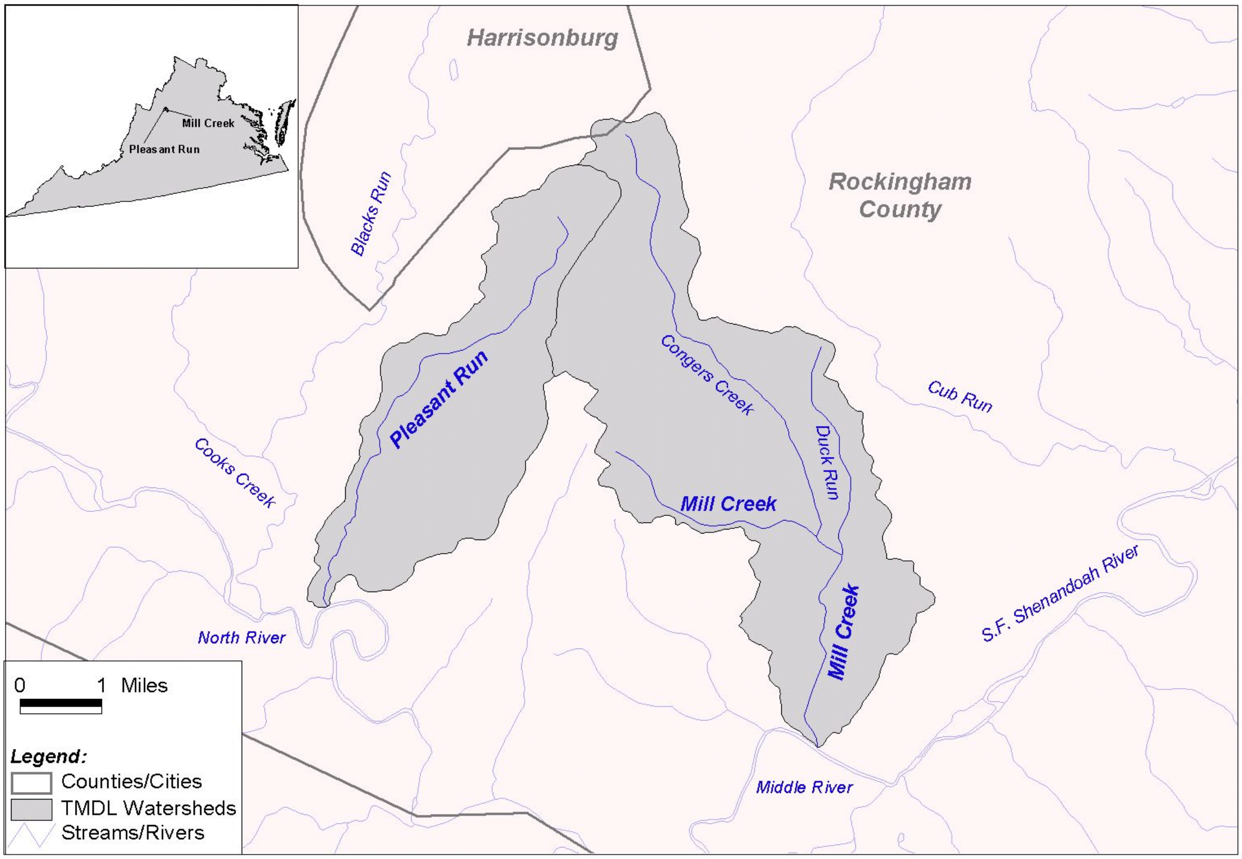

Figure 1.1 Location of TMDL watersheds

1.2 Designated Uses and Applicable Water Quality Standards

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "Water quality standards" *means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§ 62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC § 1251 et seq.).*

1.2.1 Designation of Uses (9 VAC 25-260-10)

A. All state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).

Mill Creek and Pleasant Run do not support the aquatic life designated use due to violations of the general (benthic) criteria (see Section 1.2.2).

1.2.2 Water Quality Standards

General Criteria (9 VAC 25-260-20)

A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.

Specific substances to be controlled include, but are not limited to: floating debris, oil scum, and other floating materials; toxic substances (including those which bioaccumulate); substances that produce color, tastes, turbidity, odors, or settle to form sludge deposits; and substances which nourish undesirable or nuisance aquatic plant life. Effluents which tend to raise the temperature of the receiving water will also be controlled.

1.3 Biomonitoring and Assessment

Direct investigations of biological communities using rapid bioassessment protocols, or other biosurvey techniques, are best used for detecting aquatic life impairments and assessing their relative severity (Plafkin et al. 1989). Biological communities reflect overall ecological integrity; therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act. Biological communities integrate the effects of different pollutant stressors and thus provide a holistic measure of their aggregate impact. Communities also integrate the stresses over time and provide an ecological measure of fluctuating environmental conditions.

Many state water quality agencies use benthic macroinvertebrate community data to assess the biological condition of a waterbody. Virginia uses EPA's Rapid Bioassessment Protocol (RBP II) to determine the status of a stream's benthic macroinvertebrate community. This procedure relies on comparisons of the benthic macroinvertebrate community between a monitoring station and its designated reference site. Measurements of the benthic community, called metrics, are used to identify differences between monitored and reference stations. Metrics used in the RBP II protocol include taxa richness, percent contribution of dominant family, and other measurements which provide information on the abundance of pollution tolerant versus pollution intolerant organisms. The reference station used for these streams is located on Strait Creek in Highland County, Virginia. Biomonitoring stations are typically sampled in the spring and fall of each year. The biological condition scoring criteria and the bioassessment matrix are discussed in the technical document, *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish*

(Plafkin et al. 1989). The RBPII bioassessment scoring matrix is presented in Table 1.1.

Table 1.1 Bioassessment scoring matrix (Plafkin et al. 1989)

% Compare to Reference Score (a)	Biological Condition Category	Attributes
>83%	Non-Impaired	Optimum community structure (composition and dominance).
54 - 79%	Slightly Impaired	Lower species richness due to loss of some intolerant forms.
21 - 50%	Moderately Impaired	Fewer species due to loss of most intolerant forms.
<17%	Severely Impaired	Few species present. Dominant by one or two taxa. Only tolerant organisms present.
(a) Percentage values obtained that are intermediate to the above ranges require subjective judgement as to the correct placement.		

Virginia 305(b)/303(d) guidance states that support of the aquatic life beneficial use is determined by the assessment of conventional pollutants (dissolved oxygen, pH, and temperature); toxic pollutants in the water column, fish tissue and sediments; and biological evaluation of benthic community data (VADEQ 2002). Benthic community assessments are, therefore, used to determine compliance with the General Criteria section of Virginia's Water Quality Standards (9 VAC 25-260-20). In general, the stream reach that a biomonitoring station represents is classified as impaired if the RBP ranking is either moderately or severely impaired. According to Virginia's 1998 303(d) list, the biological monitoring station on Mill Creek indicated moderate impairment and the biological monitoring station on Pleasant Run indicated severe impairment of the benthic community. As a result, these streams were listed as impaired due to violations of the general standard (aquatic life) on the 1998 303(d) list. The impairment listing for these streams remained the same in the 2000 305(b) assessment.

SECTION 2

BENTHIC TMDL ENDPOINT DETERMINATION

2.1 Reference Watershed Approach

Biological communities respond to any number of environmental stressors, including physical impacts and changes in water and sediment chemistry. According to Virginia's 1998 303(d) list, the cause of the benthic community impairment on Mill Creek and Pleasant Run was believed to be organic enrichment and low dissolved oxygen.

TMDL development requires the identification of impairment causes and the establishment of numeric endpoints that will allow for the attainment of designated uses and water quality criteria. Numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. Virginia does not currently have numeric criteria for nutrients (i.e. total phosphorus and total nitrogen), sediment, and other parameters that may be contributing to the impaired condition of the benthic community in these streams. A reference watershed approach was, therefore, used to determine the primary benthic community stressors and to establish numeric endpoints for these stressors. This approach is based on selecting non-impaired watersheds that share similar land use, ecoregion, and geomorphological characteristics with the impaired watershed. Stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to attain its designated uses. A regionally-calibrated multimetric macroinvertebrate index is used to define differences in the benthic communities in impaired and reference streams. Loading rates for pollutants of concern are determined for impaired and reference watersheds through modeling studies. Both point and nonpoint sources are considered in the analysis of pollutant sources and in watershed modeling. Numeric endpoints are based on reference watershed loadings for pollutants of concern and load reductions necessary to meet these endpoints are determined. TMDL load allocation scenarios are then developed based on an analysis of the degree to which contributing sources can be reasonably reduced. The reference watershed approach can also be used to examine physical impacts, such as hydromodification, and other controlling factors.

2.2 Watershed Characterization

2.2.1 General Information

Mill Creek and Pleasant Run are located in Rockingham County, Virginia, in the South Fork Shenandoah River basin (USGS Hydrologic Unit Code, 02070005) (Figure 1.1). Both streams eventually flow into the Potomac River, which is a tributary to the Chesapeake Bay. The waterbody identification codes (WBID, Virginia Hydrologic Unit) for Mill Creek and Pleasant

Run are VAV-B29R and VAV-B27R, respectively (VADEQ 1998). Mill Creek drains approximately 9,636 acres. Pleasant Run drains approximately 5,309 acres.

2.2.2 Geology

Both streams are located in the Shenandoah Valley of Virginia, which is part of the Valley and Ridge physiographic province. The Valley and Ridge physiographic province is a belt of folded and faulted clastic and carbonate sedimentary rocks situated west of the Blue Ridge crystalline rocks and east of the Appalachian Plateaus. The Shenandoah Valley makes up part of the Great Valley subprovince, which extends from New York southwest to Alabama. This area is characterized by broad valleys with low to moderate slopes underlain by carbonate rocks. Limestone and dolomite (which are carbonate rocks) occur beneath the surface forming the most productive aquifers in Virginia's consolidated rock formations. The gently rolling lowland of the valley floor lies at an elevation of approximately 1000 feet above sea level. Sinkholes, caves, and caverns are common in the valley due to its karst (carbonate rock) geology.

2.2.3 Soils

Soils data were obtained from the Rockingham County Soil Survey (SCS 1981) and the State Soil Geographic (STATSGO) database for Virginia, as developed by the Natural Resources Conservation Service (NRCS 1994). The primary soil associations located in each watershed are shown in Figure 2.1.

The Frederick-Lodi-Rock Outcrop and Chilhowie-Edom soil associations include valley soils that were formed in residual material weathered from limestone, dolomite, and calcareous shale. Frederick-Lodi-Rock Outcrop soils (STATSGO map unit - VA003) occupy most of the land area of each watershed. Chilhowie-Edom soils are located in the central portion of the Mill Creek watershed (STATSGO map unit - VA002). These soils associations are generally deep to moderately deep, gently sloping to steep, well drained soils that have a clayey subsoil and areas of rock outcrop, and are located on uplands underlain by limestome, dolomite, and interbedded shale. Infiltration is slow to moderate and runoff potential is moderate. Slopes typically range from 2 to 60 percent. The soils are fertile and cleared areas are commonly used for cropland and pasture. Corn and hay are the principal crops grown in these areas. Forested areas consist of northern red oak, yellow poplar, hickory, maple, black walnut, locust, eastern red cedar, and Virginia pine.

The third soil association, Monongahela-Unison-Cotaco (STATSGO map unit - VA004), exists in the downstream portion of Pleasant Run. This soil map unit follows the floodplain of the North River, Dry River, and other streams in the area. Monongahela-Unison-Cotaco soils are found on river terraces that formed in alluvial (unconsolidated sediments deposited by streams) or colluvial material (rock, soil, and other materials accumulated at the foot of a slope). These soils are generally level to moderately steep, well drained to moderately well drained, and have a loamy or clayey subsoil. Infiltration is slow in the fragipan and surface runoff is moderate. Slopes range from 0 to

25 percent. Most areas have been cleared of the original hardwood forest and used for pasture, cultivated crops, and industrial and residential sites. Corn and hay are the principal crops grown in these soils.

The Mill Creek watershed also includes the Berks-Sequoia-Weikert soil association (STATSGO map unit - VA001). These soils were formed in residual material weathered from shale and thin interbedded sandstone and limestone. These soils are generally shallow to moderately deep, gently sloping to steep, well drained soils that have a loamy or clayey subsoil.

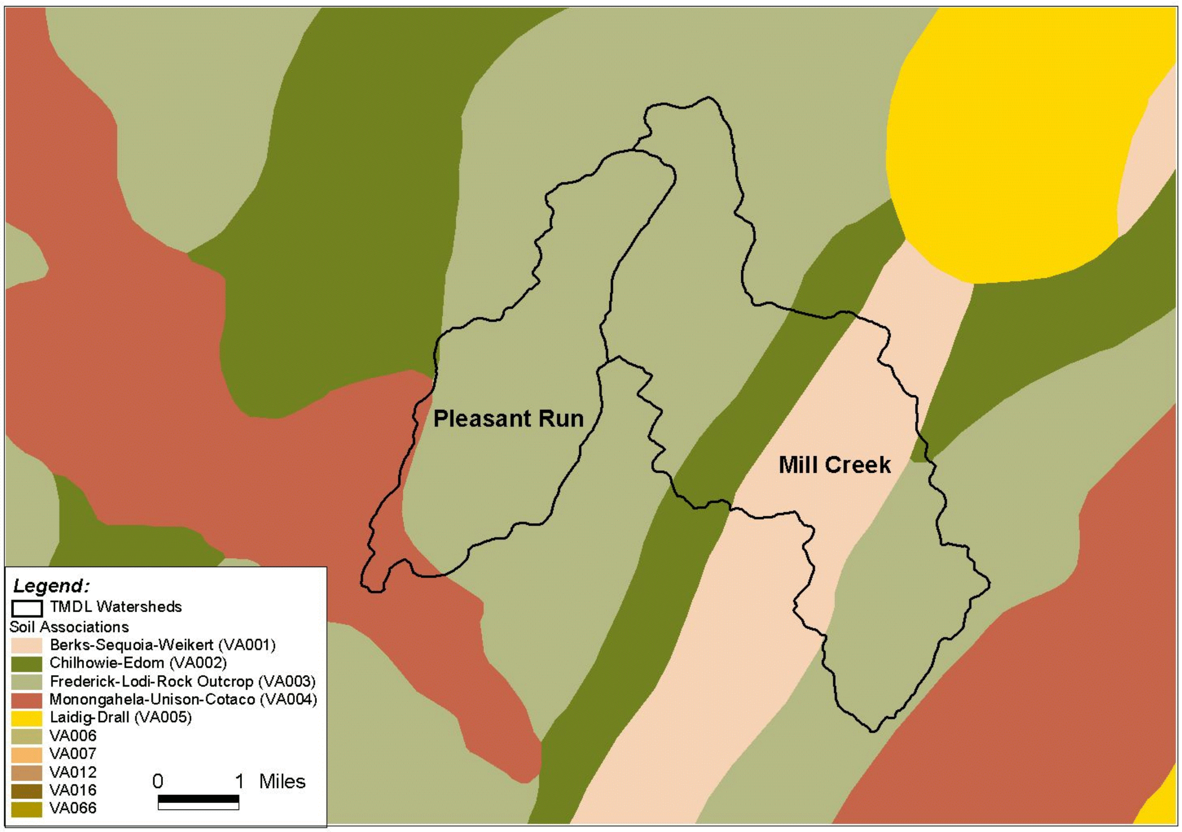

Figure 2.1 Soil associations and STATSGO map units in TMDL watersheds

2.2.4 Climate

The area's climate is typical of other regions in the Shenandoah Valley. The Blue Ridge Mountains to the east and the Alleghany Mountains to the west provide protection from the climate extremes experienced in other parts of Virginia. Weather data for these watersheds can be characterized using the Dale Enterprise meteorological station, which is located in the northwestern portion of the Cooks

Creek watershed (period of record: 1961-1990). The growing season lasts from May 1 through October 11 in a typical year (SERCC 2000). Average annual precipitation is 33.6 inches with August having the highest average precipitation (3.58 inches). Average annual snowfall is 26.5 inches, most of which occurs in January and February. The average daily temperature for the year is 53.3ºF. The average annual maximum and minimum daily temperature is 64.9ºF and 41.7ºF, respectively. The highest daily average temperatures are recorded in July (85.8ºF) and the lowest temperatures are recorded in January (21.1ºF).

2.2.5 Land Use

A GIS land use coverage was developed by the Virginia Department of Conservation and Recreation (VADCR) for these watersheds in the early 1990s using satellite imagery (Figures 2.2 and 2.3). Land uses in each watershed include various urban, agricultural, and forest categories (Table 2.1). Individual land use types were consolidated into eight broader categories that had similar erosion/pollutant transport attributes for modeling purposes.

Mill Creek

Land use in the Mill Creek watershed is predominantly agricultural in the middle and lower portions of the watershed, with residential development concentrated in the Massanetta Springs area. Pasture and hayland accounts for approximately 42% of the total land area, followed by cropland (26%), forest (16%), and urban/residential areas (16%). Of the two watersheds, Mill Creek has the highest percentage of urban development and the second highest percentage of pasture and hayland. Major tributaries include Congers Creek and Duck Run. Lake Shenandoah is a small recreational impoundment in the watershed that receives flow from Congers Creek and an unnamed tributary to the west. Lakeview Golf Course is also located in the watershed, adjacent to Lake Shenandoah.

Pleasant Run

The Pleasant Run watershed is located approximately 2 miles south of the City of Harrisonburg and is the smallest of the two TMDL watersheds. Land use in this watershed primarily consists of pasture and hayland (38%), cropland (30%), and forested areas (17%). Although the Pleasant Run watershed is located only a few miles from Harrisonburg, urban development only accounts for approximately 14% of the total land area. Residential development is concentrated along Port Republic and Ridgedale roads and in the Pleasant Valley area. Agricultural lands are interspersed with small forested areas throughout the watershed.

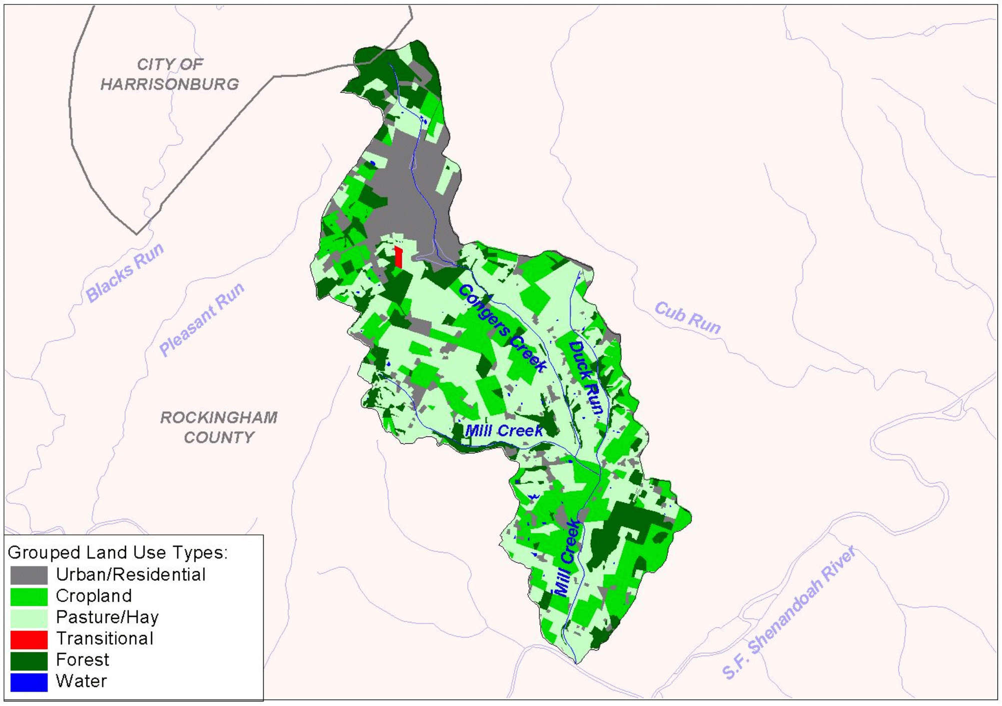

Figure 2.2 Mill Creek watershed land uses (VADCR)

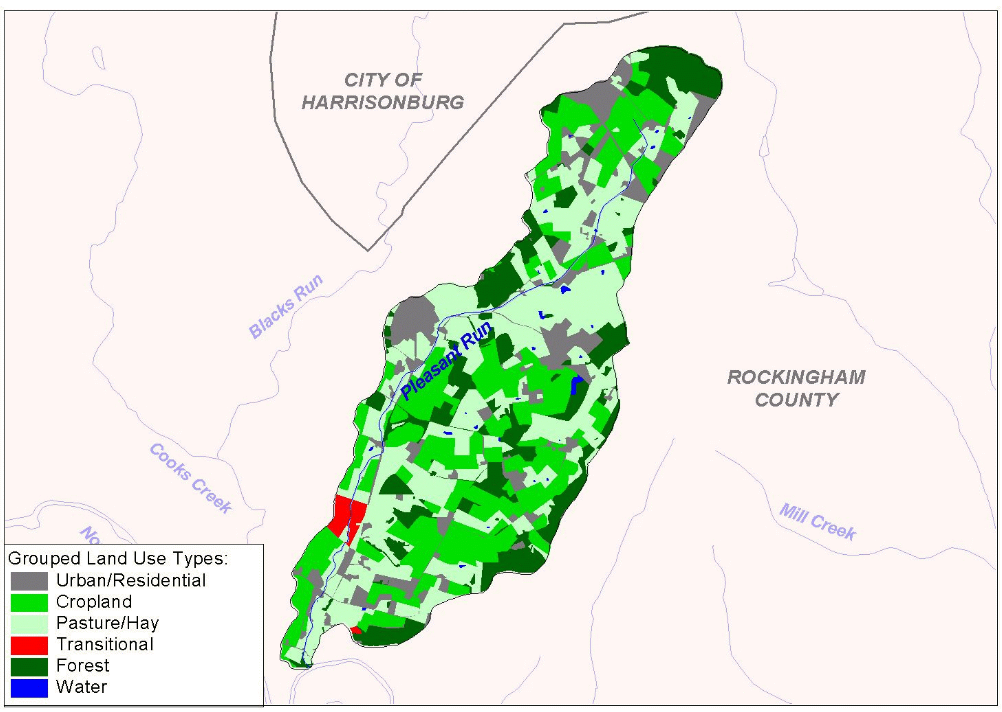

Figure 2.3 Pleasant Run watershed land uses (VADCR)

Table 2.1 VADCR land use categories and consolidated land uses

VADCR land use Categories	Consolidated land use
Row Crop (all types)	Crop Land
Improved Pasture Unimproved Pasture Overgrazed Pasture Loafing Lot Rotational Hay	Pasture/Hay
Barren Cattle Operations	Transitional
Commercial and Services Industrial Transportation Unclassified	High Intensity Commercial / Industrial / Transportation
High Density Residential Mixed Urban or Built-Up	High Intensity Residential
Low Density Residential Rural Residential Farmsteads Large Dairy Waste Operations Poultry Operations Other Feeding Operations	Low Intensity Residential
Forest Land Wooded Grazed Woodland Nurseries and Christmas Tree Farms Orchards Wooded Residential Wetlands	Forest
Water	Water

2.2.6 Stream Characteristics

Mill Creek

Mill Creek is located southeast of the City of Harrisonburg and shares the western drainage boundary with Pleasant Run. The stream originates near Cross Keys and flows in a southeasterly direction where it confluences with Congers Creek and Duck Run (Mill Creek's primary tributaries) before turning south where it flows into the North River. Massanetta Springs discharges into Congers Creek just upstream of Lake Shenandoah, a small recreational impoundment. Massanetta Springs contributes a significant flow volume to Congers Creek, which discharges to Mill Creek at Goods Mill. The Mill Creek watershed includes residential areas in the upper portion near Harrisonburg, but is predominantly rural in the middle and lower sections. Bottom lands are used for crop production and livestock grazing in many areas throughout the watershed, especially in the lower portion of Mill Creek. Riparian vegetation, which is critical to stream quality, is non-existent in heavily utilized areas. Observed water quality and habitat problems are believed to be caused by riparian disturbances and erosion problems. The upstream section of Mill Creek, above Congers Creek, and other stream sections exist in a more natural state with riparian buffers. Spring flow from Massanetta Springs provides water quality benefits, as does Lake Shenandoah which likely traps sediments and associated pollutants that are transported to the lake.

Pleasant Run

Pleasant Run is the smallest of the two TMDL streams and is located south of Harrisonburg. The stream has no named tributaries and flows southwest to its confluence with the North River. Pleasant Run has been severely impacted throughout its length by the removal of riparian vegetation, livestock grazing, and other agricultural land use activities. Pleasant Run shows evidence of de-stabilization including bank erosion, down-cutting (erosive deepening of the stream channel), and excessive sedimentation. Riparian vegetation is minimal or non-existent throughout the watershed.

2.2.7 Ecoregion

Mill Creek, Pleasant Run, Muddy Creek, and Holmans Creek are located in the Valley and Ridge ecoregion - Level III classification 67 (Woods et al. 1999) (Figure 2.4). This ecoregion extends from Wayne County, Pennsylvania, southwest through Virginia. It is characterized by alternating forested ridges and agricultural valleys that are elongated, folded and faulted. The region's roughly parallel ridges and valleys have a variety of widths, heights, and geologic materials, including limestone, dolomite, shale, siltstone, and sandstone. The valleys generally fall into two types, those underlain by limestone and those underlain by shale. The nutrient rich limestone valleys contain productive agricultural land and tend to have few streams. By contrast, the shale valleys are generally less productive, more irregular, and have greater densities of streams. Most of the streams in the limestone valleys are colder and flow all year, whereas those in the shale valleys tend to lack flow in dry periods. Limestone areas commonly have numerous springs and caves. Present-day forests cover about 50% of the region. A diversity of aquatic habitats and species of fish exist in this ecoregion due to the variation in its components.

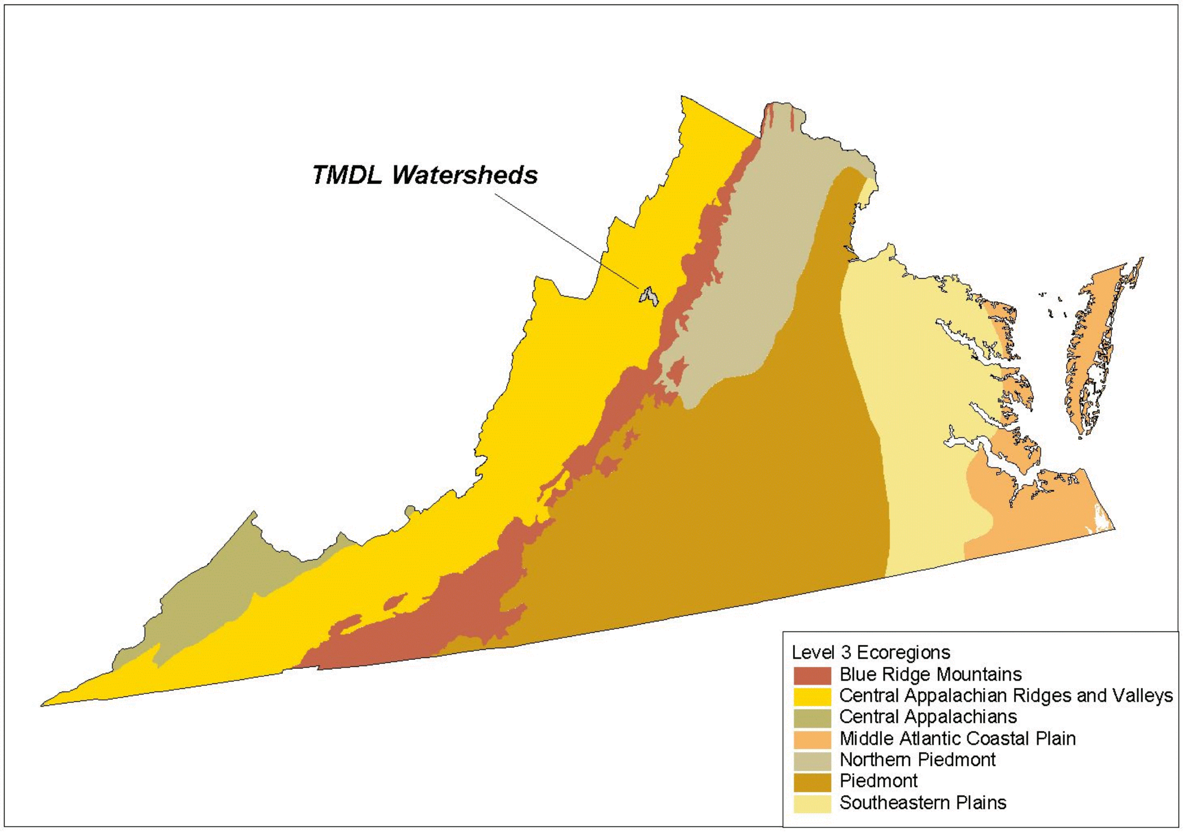

Figure 2.4 Virginia Level 3 Ecoregions

At a finer scale, the TMDL watersheds are primarily located in the Northern Limestone/Dolomite Valleys subecoregion - Level IV classification, 67a (Woods et al. 1999). This subecoregion is characterized by broad, level to undulating, fertile valleys that are extensively farmed. Karst features including sinkholes and underground streams have developed in the underlying limestone/dolomite. Interbedded with these carbonate rocks are other rocks, including shale, which give the ecoregion topographic and soil diversity. Streams tend to have gentle gradients, a perennial flow regime, and distinctive fish assemblages. Local relief typically ranges from 50-500 feet (mean sea level). The climate varies significantly because of the ecoregion's elevational and latitudinal range. The growing season varies from 145 to 180 days. Farming predominates, with scattered woodlands occurring in steeper areas. Natural vegetation mostly consists of Appalachian Oak Forest (dominated by white and red oaks) in the north and Oak/Hickory/Pine forest in the south.

2.3 Reference Watershed Selection

The reference watershed selection process is based on a comparison of key watershed, stream and biological characteristics. The goal of the process is to select one or several similar, unimpaired reference watersheds that can be used to identify benthic community stressors and develop TMDL endpoints. Reference watershed selection was based on the results of the previous benthic TMDL study for Cooks Creek and Blacks Run (USEPA 2002a). Cooks Creek and Blacks Run are located in Rockingham County adjacent to Mill Creek and Pleasant Run. Stream and watershed conditions between these streams are similar because their close proximity and shared characteristics. Of the two streams, Cooks Creek is more similar due to the greater percentage of agricultural land in the watershed and because streamflow is less influenced by urban runoff than is Blacks Run.

The Cooks Creek and Blacks Run TMDL study identified two reference watersheds in the Valley and Ridge ecoregion: Hays Creek and Upper Opequon Creek. Both watersheds were evaluated as potential reference candidates for the development of TMDLs for Mill Creek and Pleasant Run. The Hays Creek watershed, located in Rockingham and Augusta counties, was used to establish reference conditions and TMDL endpoints for Cooks Creek. Similarly, the Upper Opequon Creek watershed, located in Frederick and Clarke counties, served as the reference for Blacks Run. These two watersheds were selected for TMDL development in the previous study based on a step-wise analysis of 141 originally identified unimpaired reference sites in the Valley and Ridge ecoregion. Data used in the reference watershed selection process for Cooks Creek, Blacks Run, and these streams are shown in Table 2.2.

Table 2.2 Reference watershed selection data

Biomonitoring Data	Ecoregion Coverages
Topography	Land use Distribution
Soils	Watershed Size
Water Quality Data	Point Source Inventory

In addition, the Virginia Ridge and Valley Multimetric Bioassessment Index (VRVMBI) was developed in the prior study to provide a more detailed and reliable assessment of the benthic macroinvertebrate community in Valley and Ridge streams. This regionally-calibrated index allows for the evaluation of biological condition as a factor in the reference watershed selection process and can be used to measure improvements in the benthic macroinvertebrate community in the future. VADEQ biomonitoring data from Mill Creek and Pleasant Run were used to calculate the VRVMBI score for these streams for comparison to the two potential reference sites (Table 2.3).

Table 2.3 Bioassessment index comparison (VRVMBI)

Station ID	Stream	No. of Samples	Valley Index (VRVMBI)	
			Avg	Min - Max
Current TMDLs				
1BMIC001.00	Mill Creek	7	52	30 - 70
1BPLR000.08	Pleasant Run	8	19	6 - 27
Reference Streams				
2-HYS001.41	Hays Creek	4	67	62 - 71
1AOPE034.53	Upper Opequon Creek	1	61	n/a

2.4 Selected Reference Watershed

The Hays Creek watershed (Figure 2.5) was selected as the reference for these TMDLs based on the watershed data presented in the Cooks Creek and Blacks Run TMDL study, the degree of similarity between Cooks Creek and these nearby streams, and the VRVMBI scores for reference and TMDL streams. This stream flows into the Maury River north of the City of Lexington and drains a primarily rural watershed.

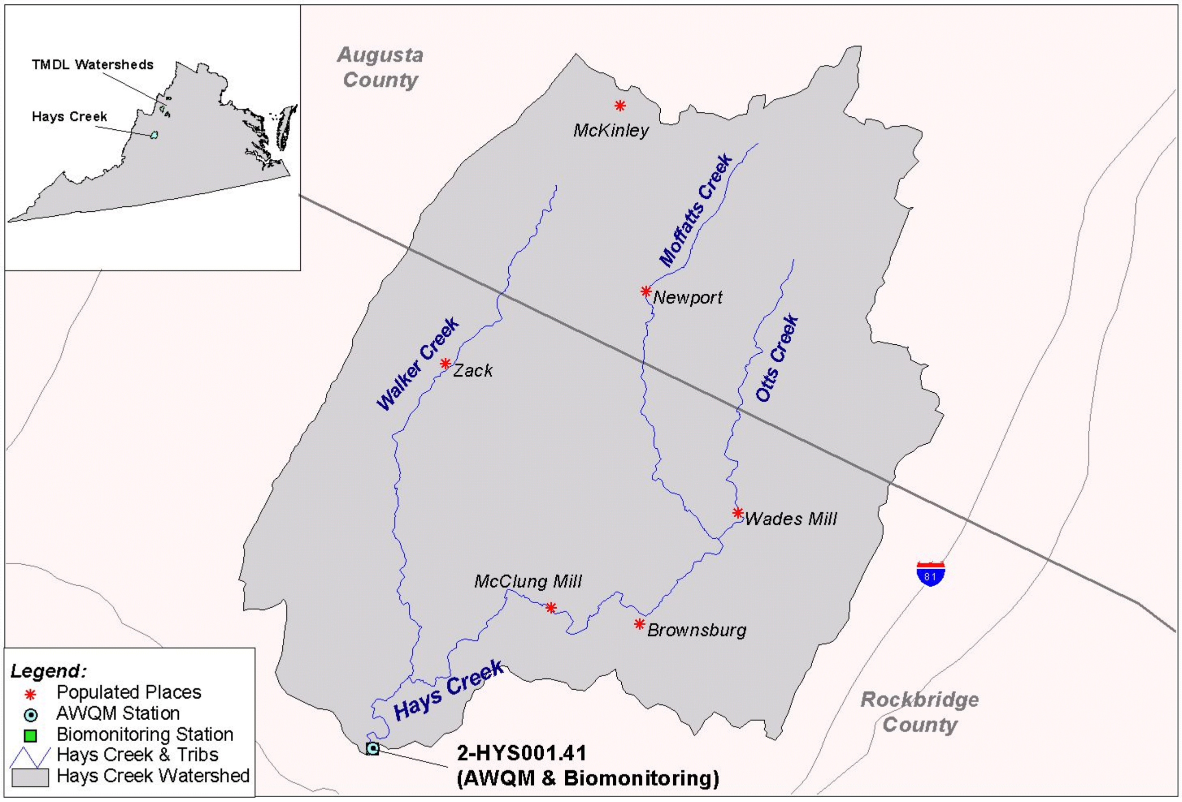

Figure 2.5 Hays Creek watershed location and monitoring stations

SECTION 3

STRESSOR IDENTIFICATION

3.1 Stressor Identification Process

Biological assessments are useful in detecting impairment, but they do not necessarily identify the cause(s) of impairment. EPA developed the *Stressor Identification: Technical Guidance Document* to assist water resource managers in identifying stressors or combinations of stressors that cause biological impairment (Cormier et al. 2000). Elements of the stressor identification process were used to evaluate and identify the primary stressors of the benthic communities in Mill Creek and Pleasant Run. Watershed and water quality data from the Cooks Creek and Blacks Run TMDL study, reference watershed data, and field observations were used to help identify candidate causes.

3.2 Candidate Causes

Based on information provided by VADEQ and watershed data collected at the beginning of the TMDL study, it was hypothesized that sedimentation and excessive nutrient loads from non-point source inputs were responsible for the listed benthic impairments. A field visit to each TMDL watershed was conducted by Tetra Tech, VADEQ, and VADCR personnel on April 22-23, 2002 to gather information on stream and watershed characteristics for stressor identification and modeling studies. The field visits took place following a period of moderate rainfall in the area, which provided information on erosion potential and nonpoint source impacts. Field observations confirmed the likelihood that sedimentation and transported nutrients loads were primarily responsible for negative impacts to the benthic macroinvertebrate community in these streams. Potential stressors and their relationships to benthic community condition are discussed below.

3.2.1 Low Dissolved Oxygen

Organic enrichment and low dissolved oxygen (DO) levels are specifically listed as likely causes on the 1998 303(d) fact sheets for Mill Creek and Pleasant Run. In general, high nitrogen and phosphorus levels can lead to increased production of algae and macrophytes, which can result in the depletion of oxygen in the water column through metabolic respiration. In addition, at higher water temperatures the concentration of dissolved oxygen is lower because the solubility of oxygen (and other gases) decreases with increasing temperature. Higher water temperatures can be caused by the loss of shading, higher evaporation rates, reduced stream flow, and other factors.

Aquatic organisms, including benthic macroinvertebrates, are dependent upon an adequate concentration of dissolved oxygen. Less tolerant organisms generally cannot survive or are outcompeted by more tolerant organisms under low dissolved oxygen conditions. This process reduces diversity and alters community composition from a natural state. Aquatic insects and other benthic organisms serve as food items for fishes, therefore, alterations in the benthic community can impact fish feeding ecology (Hayward and Margraf 1987; Leach et al. 1977).

3.2.2 Sedimentation

Excessive sedimentation from anthropogenic sources is a common problem that can impact the stream biota in a number of ways. Deposited sediments reduce habitat complexity by filling pools, critical riffle areas, and the interstitial spaces used by aquatic invertebrates. Substrate size is a particularly important factor that influences the abundance and distribution of aquatic insects. Sediment particles at high concentrations can directly affect aquatic invertebrates by clogging gill surfaces and lowering respiration capacity. Suspended sediment also increases turbidity in the water column which can affect the feeding efficiency of visual predators and filter feeders. In addition, pollutants, such as phosphorus, adsorb to sediment particles and are transported to streams through erosion processes.

3.2.3 Habitat Alteration

The relative lack of riparian vegetation along these streams was considered to be a potential factor affecting the benthic community. Minimal riparian vegetation was observed during the TMDL development field visits, especially in the Pleasant Run watershed. Adequate riparian vegetation buffers were also missing from downstream areas of Mill Creek and its tributaries. In these watersheds, riparian areas are used to grow crops and as pasture for livestock. Intensive agricultural utilization and urban encroachment (to a lesser degree) are responsible for the lack of riparian vegetation in these watersheds. Riparian areas perform many functions that are critical to the ecology of the streams that they border (Figure 3.1). Functional values include:

- Flood detention
- Nutrient cycling
- Plant roots stabilize banks and prevent erosion
- Wildlife habitat
- Canopy vegetation provides shading (decreases water temperature and increases baseflow through lower evaporation rates)

Figure 3.1 Riparian vegetation

3.2.4 Toxic Pollutants

Toxic pollutants in the water column and sediment can result in acute and chronic effects on aquatic organisms. Increased mortality rates, reduced growth and fecundity, respiratory problems, tumors, deformities, and other consequences have been documented in toxicity studies of aquatic organisms. Degraded water quality conditions and other environmental stressors can lead to higher rates of incidence of these problems.

3.3 Monitoring Stations

VADEQ monitors water quality on Mill Creek and Pleasant Run on a monthly basis as part of the Ambient Water Quality Monitoring (AWQM) program. Benthic community data are collected at separate biomonitoring stations each spring and fall. Station locations are listed in Table 3.1 and shown in Figures 3.2 and 3.3. Virginia 303(d) impaired segments are also shown in these figures. USGS streamflow gages on Mill Creek and Pleasant Run are not currently in operation.

Table 3.1 Monitoring stations on TMDL streams

Station Type	Station Number	Stream and Location
AWQM	1BMIC001.00	Mill Creek - 1 mile upstream from the mouth at the Rt. 671 bridge crossing
	1BPLR000.16	Pleasant Run - upstream of the confluence with the North River at the Rt. 867 bridge crossing
Biomonitoring	1BMIC001.00	Mill Creek - 1 mile upstream from the mouth at the Rt. 671 bridge crossing
	1BPLR000.08	Pleasant Run - just upstream of the confluence with the North River
Active USGS Streamflow Gage	n/a	n/a

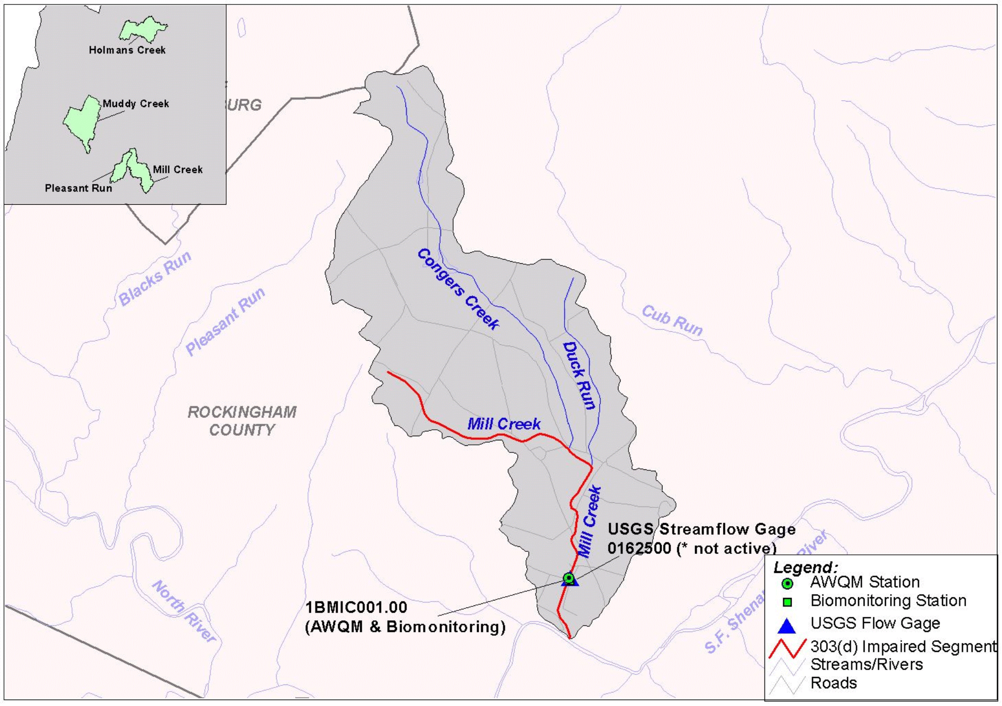

Figure 3.2 Monitoring stations on Mill Creek

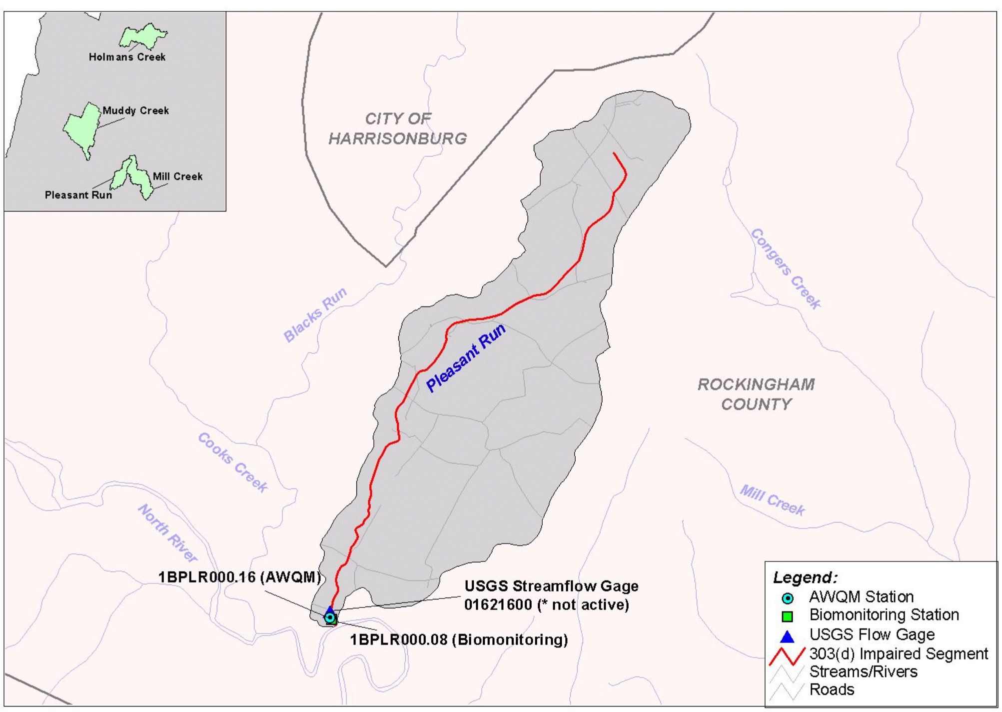

Figure 3.3 Monitoring stations on Pleasant Run

3.4 Water Quality Summary

3.4.1 Ambient Water Quality Monitoring (AWQM) Summary

Mill Creek and Pleasant Run are classified as Mountainous Zone Waters (Class IV) in Virginia Water Quality Standards (9 VAC 25-260-50). Numeric criteria for dissolved oxygen, pH, and maximum temperature for Class IV waters are shown in Table 3.2.

Table 3.2 Virginia numeric criteria for Class IV waters

Dissolved Oxygen (mg/L)			
Minimum	Daily Average	pH (standard units)	Maximum Temperature (ºC)
4.0	5.0	6.0 - 9.0	31

Water quality monitoring data were summarized to help determine general stream characteristics (Table 3.3). These data were collected by VADEQ from July 1993 through March 2002. VADEQ began analyzing for low-level concentrations of total phosphorus in these streams in the mid to late 1990s, depending on the stream in question. The total phosphorus data presented in Table 3.3 are based on the subset of data beginning with the first total phosphorus value below 0.1 mg/L that was recorded in the database for each station. The beginning date for each station's total phosphorus summary is indicated in the table.

Table 3.3 Water quality summary for TMDL streams

Parameter Name	Temp (ºC)	DO (mg/L)	pH	Turbidity (NTU)	TSS (mg/L)	NH3+NH4 (mg/L)	NO3 (mg/L)	TP (mg/L)	Fecal Coli. (cfu/100ml)
1BMIC001.00 (Mill Creek, Low-level TP summary begin date: 10/94)									
Count	99	98	99	92	101	100	100	28	10
Mean	13.68	10.27	8.08	9.8	12.6	0.06	1.58	0.11	3427
Median	13.5	10.4	8.1	5.4	6	0.04	1.24	0.04	1350
Max	28.4	15.8	8.8	119	256	0.51	7.8	1.39	16000
Min	0	5	6.9	1.2	3	0.04	0.04	0.01	25
1BPLR000.16 (Pleasant Run, Low-level TP summary begin date: 10/94)									
Count	100	99	100	93	102	102	102	29	103
Mean	13.50	10.45	8.0	20.8	24.7	0.20	4.70	0.32	5612
Median	13.45	10.8	8.0	16.1	19	0.07	4.29	0.22	2400
Max	26.2	15.4	8.9	126	153	2.26	29.2	1.7	16000
Min	1.1	2.4	7.1	2.8	3	0.04	0.29	0.01	49

By comparison, Pleasant Run had poorer water quality than Mill Creek. The minimum dissolved oxygen criteria (4 mg/L) was exceeded on one occasion in Pleasant Run during this time period. Nutrients, total suspended solids, fecal coliform bacteria, and other water quality parameters were elevated above typical background concentrations in these streams indicating degraded water quality conditions.

3.4.2 Diel DO Analysis

To investigate the potential for low DO concentrations, VADEQ collected 24-hour diel DO data on each of the TMDL streams. Primary producers (algae and macrophytes) produce oxygen during the day through photosynthesis and use oxygen during the night through respiration. This diel photosynthesis/respiration cycle results in higher DO concentrations during the day and lower DO concentrations at night.

VADEQ collected diel DO data on these streams during the week of June 10, 2002. Daily high temperatures leading up to and during the sampling period were in the upper 80s (ºF), which provided for lower dissolved oxygen concentrations in the water column. Low dissolved oxygen conditions, which stress the benthic macroinvertebrate community, typically occur in the late summer/early fall when stream temperatures are their warmest and streamflow is lower. These conditions provide information on dissolved oxygen levels that may occur during these critical periods when algal blooms commonly cause hypoxic or anoxic conditions.

Hydrolab datasondes were used to record DO concentration and water temperature at five-minute intervals over a minimum 24-hour period at each AWQM station. The diel pattern in DO concentrations for Mill Creek and Pleasant Run is shown in Figures 3.4 and 3.5. The highest DO levels at each station were recorded from 2-4 p.m. in the afternoon and the lowest DO levels were recorded from midnight until 7 a.m.

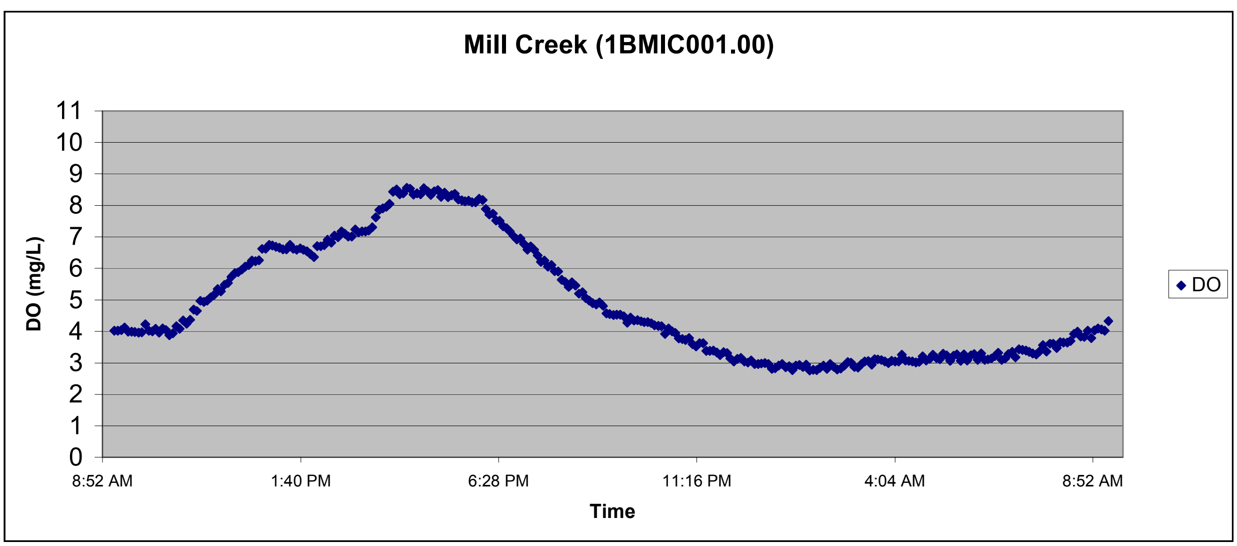

Figure 3.4 Diel dissolved oxygen pattern in Mill Creek

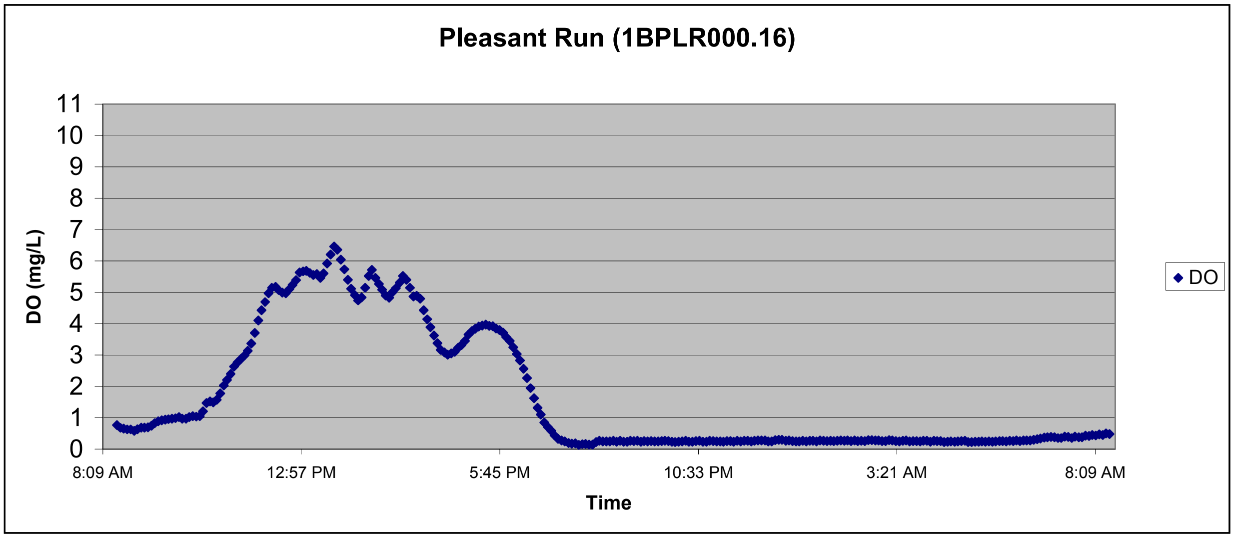

Figure 3.5 Diel dissolved oxygen pattern in Pleasant Run

Dissolved oxygen statistics for the first 24-hour period at each sampling station are presented in Figure 3.6. The interpretation of Box and Whisker plots is discussed in Section 3.8. These data were compared against the minimum and daily average DO criteria established in Virginia Water Quality Standards (9 VAC 25-260-50) to help determine whether low DO is a primary stressor of the benthic macroinvertebrate community in these streams. The median DO values for Mill Creek (4.09 mg/L) and Pleasant Run (0.37 mg/L) were below the daily average criteria of 5 mg/L. The median DO for Pleasant Run was also below the minimum criteria of 4 mg/L. The extremely low dissolved oxygen conditions in Pleasant Run indicate hypoxic conditions that could cause fish kills. For Mill Creek, 46 percent of the recorded DO values were below the minimum criteria of 4 mg/L.

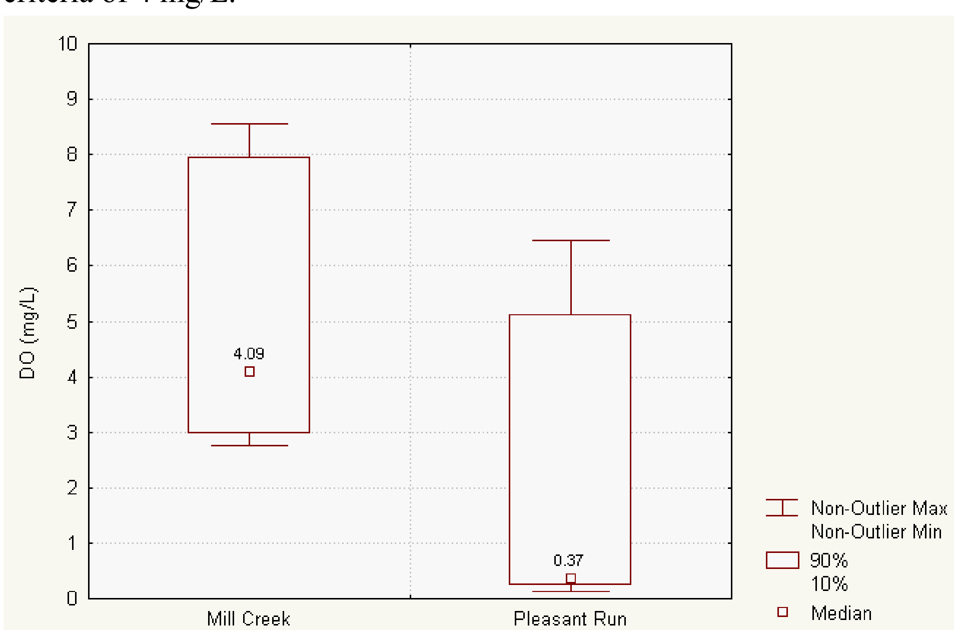

Figure 3.6 Diel dissolved oxygen statistics - 1st 24 hour period

3.5 Toxic Pollutants - Surface Water

Virginia Water Quality Standards list acute and chronic criteria for surface waters (9 VAC 25-260-140). These numeric criteria were developed for metals, pesticides, and other toxic chemicals which can cause acute and chronic toxicity effects on aquatic life and human health. Available water quality data were compared to these criteria to determine possible effects on aquatic life. Samples for water column metals were collected on April 10, 2001 for Mill Creek; metals data were not available for Pleasant Run. Ammonia data were collected during monthly ambient monitoring runs (see Table 3.3 - summary table above). No exceedances of listed parameters were identified.

3.6 Toxic Pollutants - Sediment

Sediment criteria for toxic pollutants are not specifically listed in Virginia Water Quality Standards. Consistent with VADEQ 305(b)/303(d) guidance procedures, sediment data were assessed using NOAA Effects Range-Median (ER-M) screening values. Data on sediment metals and pesticides in Mill Creek were collected by VADEQ on several occasions since 1990. Mill Creek sampling dates were July 22, 1993; August 29, 2000; and August 2, 2001. Sediment data were not available for Pleasant Run. No exceedances were noted for sampled parameters.

3.7 EPA Toxicity Testing

Chronic toxicity tests were conducted by EPA Region 3 to determine possible toxic effects on aquatic organisms in both streams (USEPA 2002b). Water (grab) samples were collected on June 3, 5, and 7, 2002 by VADEQ at the AWQM monitoring stations: Mill Creek (1BMIC001.00) and Pleasant Run (1BPLR000.08). These samples were shipped to the EPA Region 3 lab in Wheeling, West Virginia for processing. The survival/growth of fathead minnows (*Pimephales promelas*) and the survival/reproduction of *Ceriodaphnia dubia* were measured using standard toxicity testing methods. Test results do not indicate adverse effects on the survival and growth of fathead minnows and *Ceriodaphnia* in water samples collected from each stream.

3.8 Water Quality Data Comparisons

Water quality data comparisons between the TMDL streams and Hays Creek were used to help identify the causes of biological impairment. In general, stream conditions in the reference watershed are assumed to be representative of the conditions needed for the impaired stream to meet designated uses; therefore, comparative analyses of watershed and water quality data were used in stressor identification. The data period for all parameters is presented in Section 3.4.1.

Box and Whisker plots were used to compare individual water quality parameters. This type of plot displays the median value, minimum value, maximum value, and 10^{th} and 90^{th} percentile values of a population of data (Figure 3.7). The box shows the range from the 10th percentile to the 90th percentile of the values (termed the range, or R). Within the box, the median, or 50th percentile value, is displayed as a point. Whiskers show the range from the non-outlier minimum value (often 0) to the non-outlier maximum value. The non-outlier minimum value is equal to the 10th percentile value minus 1.5 times R, and the non-outlier maximum limit is equal to the 90th pecentile value plus 1.5 times R. The whiskers show the range of data values that are within these limits, not necessarily the actual 1.5x limits themselves. Extreme values are either greater than the 90th percentile value plus 3 times R, or less than the 10th percentile value minus 3 times R. Outliers are values that fall between 1.5 times R whisker thresholds and the 3 times R extreme thresholds. For graphical purposes, not all extreme and outlier values are displayed in the following box plots.

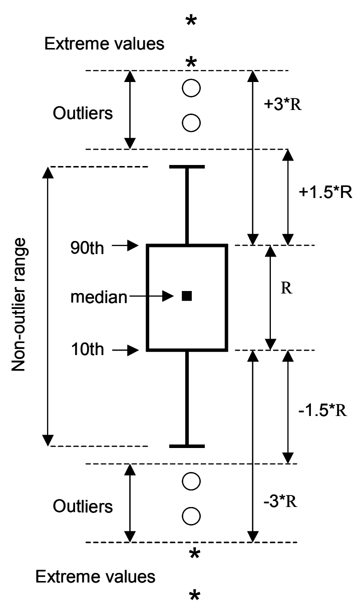

Figure 3.7 Box and whisker plot example

Median dissolved oxygen levels for Mill Creek and Pleasant Run were lower than in Hays Creek during this time period (Figure 3.8). Mill Creek had the lowest median DO concentration (10.4 mg/L), followed by Pleasant Run. The wide range in DO concentrations in Mill Creek and Pleasant Run indicate unstable dissolved oxygen conditions that are indicative of organic enrichment. The non-outlier range for Pleasant Run exceeds Virginia's daily average and minimum DO criteria for these streams. These data support the results of the diel DO analysis referenced in Section 3.4.2.

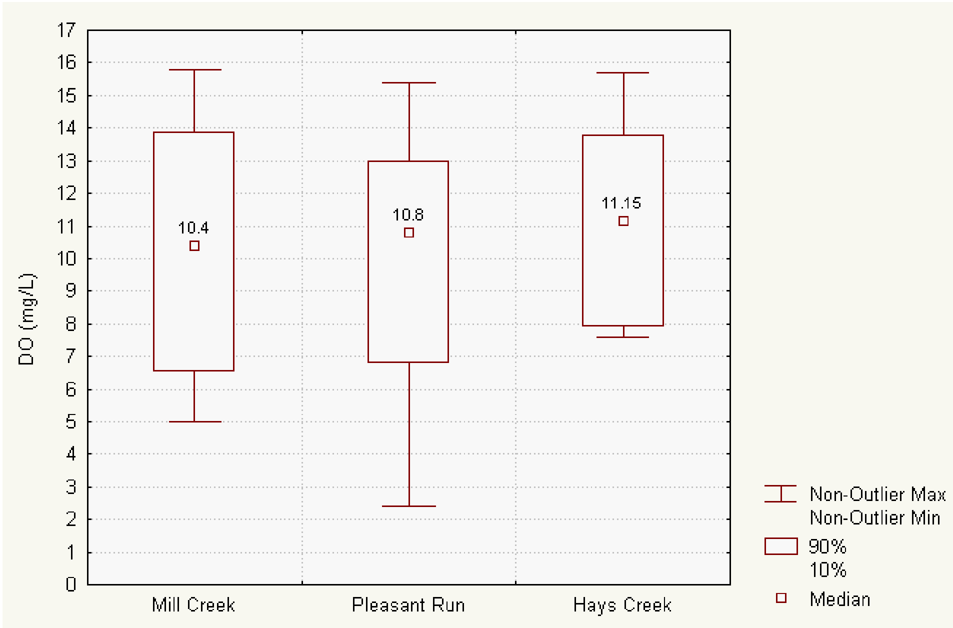

Figure 3.8 Comparison of AWQM dissolved oxygen data

Median surface water temperatures were higher in both impaired streams as compared to Hays Creek (Figure 3.9). Pleasant Run had the highest median value (13.5 ºC). The relative lack of riparian vegetation in the impaired watersheds is likely responsible for elevated water temperatures. Other habitat alterations which are present may also be contributing to this condition.

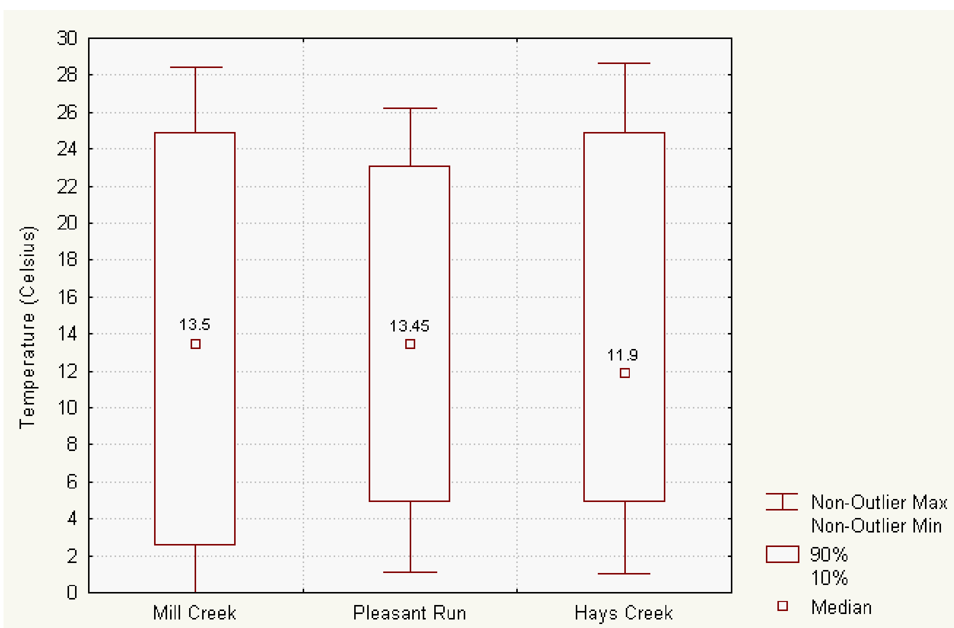

Figure 3.9 Comparison of AWQM temperature data

Nutrient data showed a similar trend between impaired streams and the reference site. Overall, median nutrient concentrations were consistently higher in the Mill Creek and Pleasant Run as compared to Hays Creek. Ammonia concentrations (NH3+NH4) in Pleasant Run ranged from 0.04 mg/L to 0.87 mg/L (Figure 3.10, non-outlier range). The 90th percentiles for Mill Creek and Pleasant Run exceeded the 90th percentile for Hays Creek. This same relationship is exhibited in the nitrate data, with Pleasant Run having the highest median concentration (4.285 mg/L) (Figure 3.11). Total phosphorus (TP) levels were also higher in Mill Creek and Pleasant Run, as compared to Hays Creek (Figure 3.12).

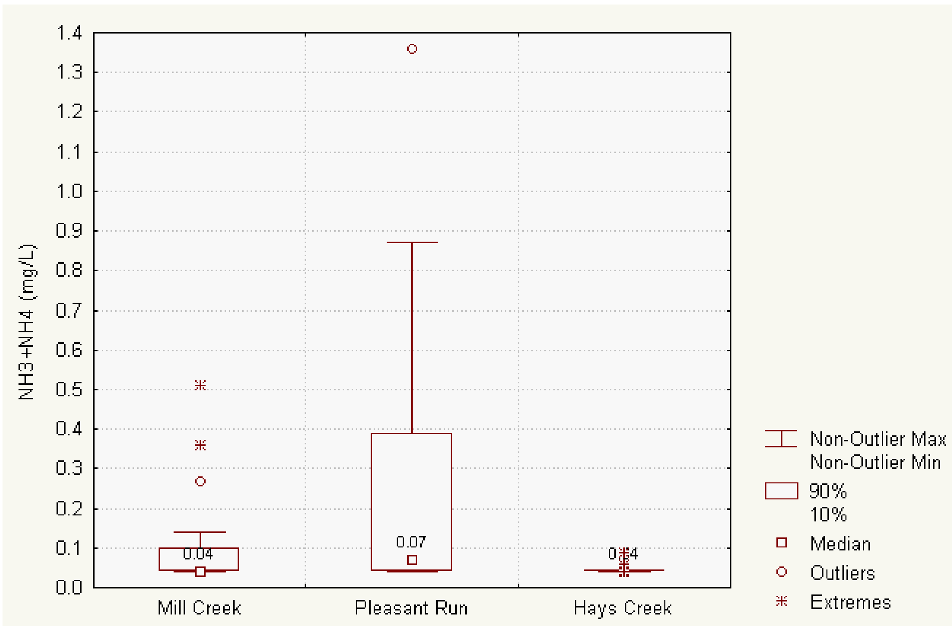

Figure 3.10 Comparison of AWQM ammonia data

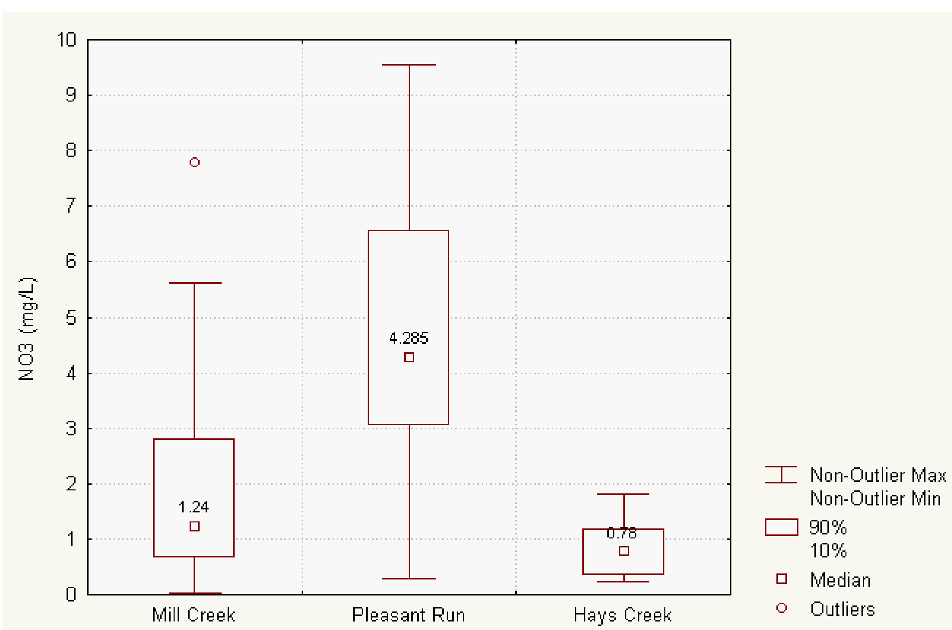

Figure 3.11 Comparison of AWQM nitrate data

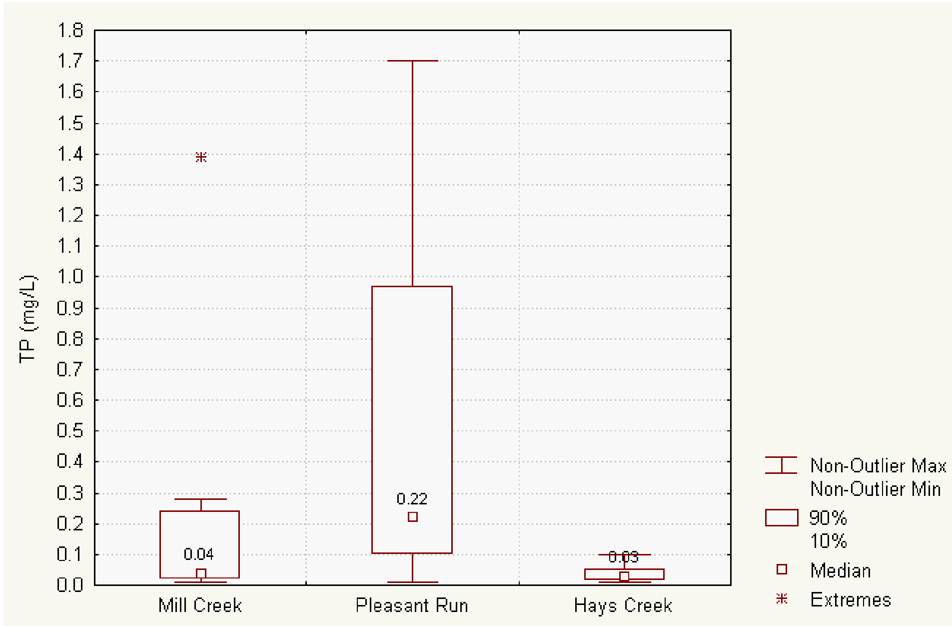

Figure 3.12 Comparison of AWQM total phosphorus data (low-level)

Total suspended solids (TSS) data were used to examine the likelihood of sedimentation impacts on the benthic macroinvertebrate community (Figure 3.13). TSS values were highest in Pleasant Run, by comparison. These data also indicate that Mill Creek had lower TSS concentrations than Hays Creek; however, in a separate analysis Mill Creek had a higher median TSS concentration (8mg/L) than Hays Creek (6 mg/L) during low flow periods (lowest 50% flows). Higher TSS concentrations during low flow periods are indicative of a more persistent sedimentation problem.

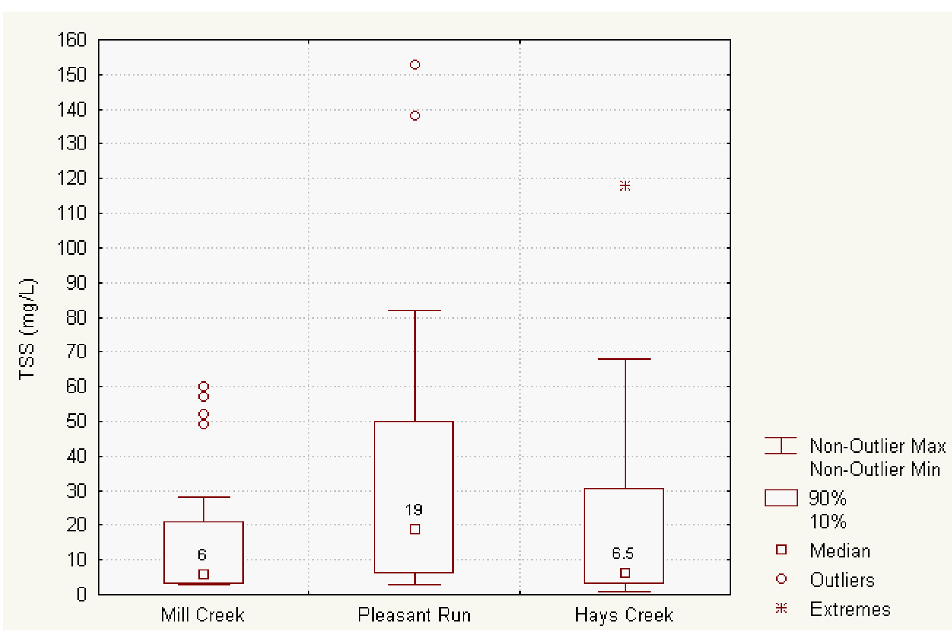

Figure 3.13 Comparison of AWQM total suspended solids data

3.9 Stressors and Selected Endpoints

3.9.1 Low Dissolved Oxygen

Organic enrichment and low dissolved oxygen were listed as likely causes of the benthic impairment in Mill Creek and Pleasant Run, according to Virginia's 1998 303(d) list. Water quality comparisons with reference stream conditions and the results of the diel DO analysis support this conclusion. Mill Creek and Pleasant Run exhibited dissolved oxygen levels that were low and persistent enough to severely stress the benthic community. High nutrient concentrations in these streams increase algal growth and community respiration, especially during summer low flow periods, which leads to lower dissolved oxygen levels. A reduction in excess nutrient loading will subsequently decrease algal productivity in the water column resulting in an increase in dissolved oxygen concentration.

Typically in aquatic ecosystems the quantities of trace elements are plentiful; however, nitrogen and phosphorus may be in short supply. The nutrient that is in the shortest supply is called the limiting nutrient because its relative quantity affects the rate of production (growth) of aquatic biomass. If the nutrient load to a waterbody can be reduced, the available pool of nutrients that can be utilized by plants and other organisms will be reduced and, in general, the total biomass can subsequently be decreased as well (Novotny and Olem 1994). In most efforts to control eutrophication processes in waterbodies, emphasis is placed on the limiting nutrient.

Phosphorus is the limiting nutrient for aquatic growth in most freshwater bodies. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of nitrogen to the amount of phosphorus is often used to make this determination (Thomann and Mueller 1987). If the nitrogen/phosphorus ratio is less than 10, nitrogen is limiting; if this ratio is greater than 10, phosphorus is the limiting nutrient. The nitrogen/phosphorus ratios for Mill Creek and Pleasant Run were 17 and 21, respectively. These ratios indicate that phosphorus is the limiting nutrient in all cases. A phosphorus TMDL was, therefore, developed for each stream. Controlling the phosphorus loading to the impaired waterbodies will limit plant growth and reduce eutrophication. As described in Section 6, the numeric endpoint for phosphorus was based on the average annual load in tons/year of the Hays Creek reference watershed.

The loss of riparian buffers and other habitat alterations also contribute to depressed dissolved oxygen conditions in these streams. At higher water temperatures the concentration of dissolved oxygen is lower. As shown in Section 3.8, water temperatures were generally higher in TMDL streams than in the reference stream (AWQM data). Elevated water temperatures are likely due the loss of riparian vegetation which provides shading (canopy vegetation cools the stream and reduces evaporation).

3.9.2 Sedimentation

Excessive sedimentation is considered to be a primary cause of the listed benthic impairments in these streams. This determination is based on field observations and ambient water quality monitoring data which indicate high levels of TSS. Agricultural and urban runoff, stream bank de-stabilization, the loss of riparian buffers, and other processes have resulted in sedimentation impacts to the benthic community in these streams. Sediment TMDLs and associated load reductions were, therefore, developed for these streams. As described in Section 6, the numeric endpoint for sediment loading was based on the average annual load in tons/year of the reference watershed. Reductions in sediment loading will result in corresponding reductions in phosphorus and other pollutants that adsorb to sediment particles.

3.9.3 Habitat Alteration

Habitat alterations combine a complex interaction of stressors. Habitat quality in these streams has been primarily affected by agricultural practices, especially the intensive use of riparian areas for agricultural production.

The complex suite of stressors caused by habitat modification include: decreased detrital input which serves as an energy source; decreased woody debris which provides substrate; increased erosion; flow alterations which cause stream channel impacts and affect water quality; the loss of pools and riffles due to sedimentation and other causes; and other stressors (Tarplee et al. 1971, Karr and Schlosser 1977, Yount and Niemi 1990, Allan 1995). Field observations, analyses of water quality and biomonitoring data, and past studies of urban and agricultural watersheds provide evidence of these impacts.

Although these TMDLs do not directly address habitat modification, which is not a pollutant, reductions in sediment and nutrient loads are expected to benefit habitat conditions. Management practices expected to be used in reducing sediment and nutrient loads will include riparian zone management that benefits habitat conditions as well, through stream shading and stream bank protection.

3.9.4 Toxic Pollutants

Toxic pollutants in the water column and sediment were investigated as potential stressors of the benthic community. Analyses of available water quality and sediment data do not indicate acute or chronic levels of metals, pesticides, or other toxins in these streams. In addition, EPA chronic toxicity tests, using water samples collected from Mill Creek and Pleasant, do not indicate adverse effects on the survival and growth of test organisms (USEPA 2002b). As a result, TMDLs for toxic pollutants were not required.

SECTION 4

SOURCE ASSESSMENT - SEDIMENT AND PHOSPHORUS

Point and nonpoint sources of sediment and phosphorus were assessed in TMDL development. The source assessment was used as the basis of model development and analysis of TMDL allocation options. A variety of information was used to characterize sources in impaired and reference watersheds including: agricultural and land use information provided by VADCR and other sources, water quality monitoring and point source data provided by VADEQ, local housing and other spatial coverages provided by Rockingham County, past TMDL studies, literature sources, and other information. Procedures and assumptions used in estimating sediment and phosphorus sources in the impaired watersheds are described in the following sections. Similar procedures were used to derive the required input data for reference watersheds, although the specific data products used varied for each watershed. Whenever possible, data development and source characterization was accomplished using locally-derived information.

4.1 Assessment of Nonpoint Sources

Virginia's 1998 303(d) list identifies agriculture as the primary source of pollutants in the Mill Creek and Pleasant Run watersheds. Both watersheds were assessed by VADCR as having a high potential for nonpoint source pollution based on land use, soils, and other watershed characteristics (refer to Section 2).

Erosion of the land results in the transport of sediment to receiving waters through various processes. Factors that influence erosion include characteristics of the soil, vegetative cover, topography, and climate. Nonpoint sources, such as agricultural land uses and construction areas, are large contributors of sediment because the percentage of vegetative cover is typically lower. Urban areas can also contribute quantities of sediment to surface waters through the build-up and eventual washoff of soil particles, dust, debris, and other accumulated materials. Pervious urban areas, such as lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses. In addition, streambank erosion and scouring processes can result in the transport of additional sediment loads. Timber operations represent another potential source of sedimentation. Although the sediment yield from undisturbed forests is generally low, clear-cut areas can contribute significant sediment loads.

Phosphorus, because of its tendency to adsorb to soil particles and organic matter, is primarily transported in surface runoff with eroded sediments. Under normal conditions, phosphorus is scarce in the aquatic environment; however, land disturbance activities and fertilizer applications increase phosphorus loading in surface waters. Nonpoint sources of phosphorus include soil erosion, runoff from urban and agricultural lands, animal waste, residential septic systems, and groundwater.

4.1.1 Agricultural Land

Agricultural land was identified as a major source of nutrients and sediment in the Mill Creek, and Pleasant Run watersheds. Agricultural runoff can contribute increased pollutant loads when farm management practices allow soils rich in nutrients from fertilizers or animal waste to be washed into the stream, increasing in-stream sediment and phosphorus levels. The erosion potential of cropland and over-grazed pasture land is particularly high due to the lack of year-round vegetative cover. The use of cover crops and other management practices have been shown to reduce the transport of pollutant loads from agricultural lands.

VADCR land use types in the Mill Creek and Pleasant Run watersheds are shown in Table 2.1. Consolidated land uses are also shown in this table and represent similar land use categories. Watershed land use percentages are presented in Section 2.2.5. The major crops grown in Rockingham County and Shenandoah County are corn, hay, soybeans, barley, and wheat.

4.1.2 Livestock

Rockingham County ranks as the top agriculture producing county in Virginia, due in large part to livestock sales (NASS 1997). Rockingham County is the leading producer of poultry (broilers, pullets, layers, and turkeys) and dairy cattle, ranks third in beef cattle production, and is second in sheep and lamb production (VASS 2001). Horses, goats, and other livestock animals had very small populations as compared to the major livestock species listed above.

Grazing animals, such as beef and dairy cattle, deposit manure (and, therefore, nutrients) on the land surface, where it is available for washoff and delivery to receiving waterbodies. Spreading animal manure on agricultural lands also contributes to nutrient washoff. Livestock traffic, especially along stream banks, disturbs the land surface and reduces vegetative cover causing an increase in erosion from these areas.

4.1.3 Forest Land

Silviculture, especially clear-cut operations, can be an important nonpoint source of sediment and other pollutants. As discussed in Section 2.2.5, the percentage of forest land (evergreen, deciduous, and mixed forest) in both watersheds is very low. Urban and agricultural development in Rockingham County has resulted in the loss of mature forest areas. The remaining forest lands, generally, occupy higher elevations and agriculturally unproductive areas. The sediment and phosphorus yield from undisturbed forest lands, especially during the growing season, is low due to the amount of dense vegetative cover which stabilizes soils and reduces rainfall impact. Clear-cut areas have a high erosion potential and are represented in the VADCR land use type “Barren”.

4.1.4 Urban Areas

Urban land uses represented in the VADCR land use coverage include commercial, industrial, transportation, and residential areas. Watershed differences in urban land use distribution are discussed in Section 2.2.5.

Urban land uses consist of pervious and impervious areas. Stormwater runoff from impervious areas, such as paved roads and parking lots, contributes pollutants that accumulate on these surfaces directly to receiving waters without being filtered by soil or vegetation. Sediment and phosphorus deposits in impervious areas originate from vehicle exhaust, industrial and commercial activities, fertilizer spills, outdoor storage piles, wildlife and domestic pet waste, and other sources. Combined sewer overflows (CSOs) and leaking sewer lines may also be a source of nutrients in some urban areas. According to Novotny and Olem (1994), phosphorus concentrations in urban runoff range from 0.2 to 1.7 mg/L. In addition, stormwater runoff can cause streambank erosion and bottom scouring through high flow volumes, resulting in increased sedimentation and other habitat impacts.

The primary urban sources of sediment and phosphorus are construction sites and other pervious lands. Construction sites have high erosion rates due to the removal of vegetation and top soil. Typical erosion rates for construction sites are 35 to 45 tons per acre per year as compared to 1 to 10 tons per acre per year for cropland. Residential lawns and other green spaces contribute sediment in the same fashion as low-intensity pasture areas or other similar land uses. Fertilizer application on lawns can be a significant source of phosphorus and other pollutants. Wildlife and domestic pet waste is also deposited on pervious urban lands.

Urban land use areas were separated into pervious and impervious fractions based on the estimated percent impervious surface of each urban land use category. Field observations and literature values were used to determine the effective percent imperviousness of urban land uses (Table 4.1). Construction sites, quarries, and other bare soil areas are represented as “Barren” in the VADCR land use coverage.

Table 4.1 Percent imperviousness of urban land uses in TMDL watersheds

Urban land uses	Percent impervious
High Intensity Commercial / Industrial / Transportation	50%
High Intensity Residential	40%
Medium Intensity Residential	30%
Low Intensity Residential	20%

4.1.5 Septic Systems

On-site septic systems have the potential to deliver nutrients to surface waters due to system failure and malfunction. Septic systems treat human waste using a collection system that discharges liquid waste into the soil through a series of distribution lines that comprise the drain field. In properly functioning (normal) systems, phosphates are adsorbed and retained by the soil as the effluent percolates through the soil to the shallow saturated zone. Therefore, normal systems do not contribute phosphorus loads to surface waters. A septic system failure occurs when there is a discharge of waste to the soil surface where it is available for washoff. As a result, failing septic systems can contribute high phosphorus loads to surface waters. Short-circuited systems (those located close to streams) and direct discharges also contribute significant nutrient loads.

The population served by each type of septic system (normal, short-circuited, ponded, and direct discharge) in each of the impaired watersheds was determined using the following methods.

Mill Creek and Pleasant Run

The number of septic systems in the Mill Creek and Pleasant Run watersheds were determined based on the previous fecal coliform TMDL developed for Mill Creek and Pleasant Run (VADEQ and VADCR 2000). According to the Mill Creek and Pleasant Run fecal coliform TMDL reports, there are a total of 601 unsewered households in the Mill Creek watershed and 338 unsewered homes in the Pleasant Run watershed. This information was determined using "housing and sewer GIS coverages provided by Rockingham County (E-911) data. Each unsewered household was classified into one of three age categories (pre-1964, 1964-1984, and post-1984) based on USGS 7.5-minute topographic maps that were initially created using 1964 photographs and were photo-revised in 1984. Professional judgement (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.) was applied in assuming that septic system failure rates for houses in the pre-1964, 1964-1984, and post-1984 categories were 40, 20, and 5 percent, respectively" (VADEQ and VADCR 2000). The number of short-circuited systems was estimated based on the proximity of unsewered houses to the closest perennial stream. Unsewered houses located within 50 feet (approximately 15 meters) of a perennial stream were assumed to have a short-circuited septic system. These systems are located close enough to surface waters, such that negligible adsorption of phosphorus takes place (Haith et al. 1992). The population on septic was determined using the 2000 Rockingham County census multiplier of 2.61 persons/household (U.S. Census Bureau 2000).

In some cases, human waste is directly deposited into surface waters from houses without septic systems. These direct discharges are called "straight pipes" and are illegal under Virginia regulations. Houses with straight pipes are typically older structures that are located close to a waterbody. The number of straight pipes in each watershed was determined based on housing age and distance to a perennial stream. Older houses (pre-1964 and 1964-1984) located within 150 feet of a perennial stream were assumed to have a straight pipe according to the following percentages: pre-1964 (10 percent straight pipes), 1964-1984 (2 percent straight pipes) (VADEQ and VADCR

2000). Based on these criteria, there are no straight pipes in the Mill Creek or Pleasant Run watersheds. Table 4.2 presents the septic system information for each watershed.

Table 4.2 Septic population in TMDL watersheds

Watershed	Normal	Ponded (Failing)	Short-circuited	Direct discharge
Mill Creek	452	144	5	0
Pleasant Run	257	75	6	0

4.1.6 Groundwater

Agriculture and septic systems are two major sources that enrich the groundwater. Phosphorus concentrations in groundwater were based on the results from a nationwide study of mean dissolved nutrients as measured in streamflow (as reported in Haith et al. 1992). The relative percentage of agriculture and forest land in each watershed and septic population data were used to estimate groundwater phosphorus concentrations from the study results.

4.2 Assessment of Point Sources

Point sources can contribute sediment and phosphorus loads to surface waters through effluent discharges. These facilities are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) program that is managed by VADEQ.

VPDES individual permits are issued to facilities that must comply with permit conditions which include specific discharge limits and requirements. There no “individual permit” point source facilities in the Mill Creek and Pleasant Run watersheds.

General permits are granted for smaller facilities, such as domestic sewage discharges, that must comply with a standard set of permit conditions, depending on facility type. Currently, there are three VPDES domestic sewage discharge general permits in the Mill Creek watershed and none in the Pleasant Run watershed (Table 4.3). Each facility discharges less than 1,000 gallons per day (gpd). The annual sediment load contributed by each facility was calculated based on the permitted TSS concentration of 30 mg/L and the maximum allowable flow (1,000 gpd). These permits do not contain a numeric limit for phosphorus, therefore, phosphorus loads were calculated using a phosphorus concentration of 15 mg/L, based on secondary treatment levels required under the general permit, and the maximum allowable flow (J. Schneider, personal communication).

Table 4.3 VPDES point source facilities and pollutant loads

Stream	Facility	VPDES Permit No.	Discharge Type	Design Flow (gpd)	Sediment Load (pounds/year)	Phosphorus Load (pounds/year)
Mill Creek	Single Family House - Route 1, Port Republic	VAG401620	SFH	<1,000	92	46
	Single Family House - Route 276	VAG401103	SFH	<1,000	92	46
	Mill Creek Church of the Brethren - 7600 Port Republic	VAG401465	Private	<1,000	92	46
Pleasant Run	N/A	N/A	N/A	N/A	N/A	N/A

SECTION 5

WATERSHED MODELING

5.1 Overall Technical Approach

As discussed in Section 2.1, a reference watershed approach was used in this study to develop TMDLs for Mill Creek and Pleasant Run. A watershed model was used to simulate the sediment and phosphorus loads from potential sources in impaired and reference watersheds. The watershed model used in this study was the Generalized Watershed Loading Functions (GWLF) model (Haith and Shoemaker 1987). GWLF modeling was accomplished using the BasinSim 1.0 watershed simulation program, which is a windows-based modeling system that facilitates the development of model input data and provides additional functionality (Dai et al. 2000). Numeric endpoints were based on the unit-area loading rates that were calculated for the reference watershed. TMDLs were then developed for each impaired stream segment based these endpoints and the results from load allocation scenarios.

5.2 Watershed Model

TMDLs were developed using BasinSim 1.0 and the GWLF model. The GWLF model, which was originally developed by Cornell University (Haith and Shoemaker 1987, Haith et al. 1992), provides the ability to simulate runoff, sediment, and nutrient loadings from watersheds given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. GWLF is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on daily water balance totals that are summed to give monthly values.

GWLF is an aggregate distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous with respect to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for subsurface flow contributions. Daily water balances are computed for an unsaturated zone as well as for a saturated subsurface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss/erosion (K), the length/slope factor (LS), the vegetation cover factor (C), and the conservation practices factor (P). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. Surface nutrient losses are determined by applying dissolved nitrogen and phosphorus coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area. Point source discharges also can contribute to dissolved loads to the stream and are specified in terms of kilograms per month. Manured areas, as well as septic systems, also can be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Subsurface losses are calculated using dissolved nitrogen and phosphorus coefficients for shallow groundwater contributions to stream nutrient loads, and the subsurface submodel considers only a single, lumped-parameter contributing area. Evapotranspiration is determined using daily weather data and a cover factor dependent on land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values. All of the equations used by the model can be found in the original GWLF paper (Haith and Shoemaker 1987) and GWLF User's Manual (Haith et al. 1992).

For execution, the model requires three separate input files containing transport, nutrient, and weather-related data. The transport file (TRANSPRT.DAT) defines the necessary parameters for each source area to be considered (e.g., area size, curve number) as well as global parameters (e.g., initial storage, sediment delivery ratio) that apply to all source areas. The nutrient file (NUTRIENT.DAT) specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations). The weather file (WEATHER .DAT) contains daily average temperature and total precipitation values for each year simulated.

5.3 Model Setup

Watershed data needed to run the GWLF model in BasinSim 1.0 were generated using GIS spatial coverages, water quality monitoring and streamflow data, local weather data, literature values, and other information. Watershed boundaries for Mill Creek and Pleasant Run were delineated using the VADCR land use coverage for each watershed. Reference watersheds were delineated using USGS 7.5 minute digital topographic maps (24K DRG - Digital Raster Graphics). The reference watershed outlet is located at the VADEQ biomonitoring station on Hays Creek. To equate target and reference watershed areas for TMDL development, the total area for the reference watershed was reduced to be equal to the area of its paired target watershed, after hydrology calibration. To accomplish this, land use areas (in the reference watershed) were proportionally reduced based on the percent land use distribution. As a result, the total watershed area for Hays Creek was reduced to be equal to the Mill Creek and Pleasant Run watershed areas.

Local rainfall and temperature data were used to simulate flow conditions in modeled watersheds. Hourly precipitation and daily temperature data were obtained from local National Climatic Data Center (NCDC) weather stations and other sources. Daily maximum and minimum temperature values were converted into daily averages for modeling purposes. Weather stations that correspond with each modeled watershed are shown in Table 5.1. The period of record selected for model runs (April 1, 1991 through March 31, 1998) was based on the availability of recent weather data and corresponding streamflow records. The weather data collected at the NCDC station of Dale Enterprise were used to construct the weather file used in all watershed simulations. Hays Creek modeling was based on precipitation data collected at the NCDC station on Kerrs Creek and temperature data collected at the NCDC station in nearby Lexington, Virginia. The calculated daily average temperatures for Lexington were reduced by 1ºC to adjust for the difference in elevation between Lexington and the Hays Creek watershed.

Table 5.1 Weather stations used in GWLF models

Watershed	Weather Station	Data Type	Data Period
Mill Creek/ Pleasant Run	Dale Enterprise	Hourly Precip	4/1/91 - 3/31/98
		Daily Max/Min Temp	4/1/91 - 3/31/98
Hays Creek	Kerrs Creek	Hourly Precip	4/1/90 - 3/31/97
	Lexington	Daily Max/Min Temp	4/1/90 - 3/31/97

Daily streamflow data are needed to calibrate watershed hydrologic parameters in the GWLF model. The USGS does not currently monitor daily flows on Mill Creek and Pleasant Run. Table 5.2 lists the USGS gaging stations used in watershed modeling along with their period of record for the appropriate watersheds.

Table 5.2 USGS gaging stations used in modeling studies

Modeled Watershed	USGS station number	USGS gage location	Data Period
Mill Creek/ Pleasant Run	01632082	Linville Creek at Broadway, VaA	8/9/1985-9/30/1998
Mill Creek	0162500	Mill Creek at Route 671 near Port Republic, VA	9/1993-9/1996 (monthly observations)
Pleasant Run	01621600	Pleasant Run at Rt. 867, near Mount Crawford, VA	9/1993 - 9/1996 (monthly observations)

For Mill Creek and Pleasant Run, only monthly observations of stream flow were available. As a result, streamflow data from nearby Linville Creek were used to estimate daily flows for Mill Creek and Pleasant Run. Flow data were corrected based on differences in watershed size. Considering that the Linville Creek watershed shares similar geomorphology, hydrology, and land use characteristics as the Mill Creek and Pleasant Run, this method was deemed appropriate.

Linville Creek flow data were corrected based on watershed size for Mill Creek and Pleasant Run and compared to available flow data for each of these streams. Figures 5.1 and 5.2 present comparisons of the corrected Linville Creek flow data to the observed flow data for Mill Creek and Pleasant Run. The plots show that the corrected flow at the Linville Creek USGS gage is in reasonable agreement with the observed data from these streams.

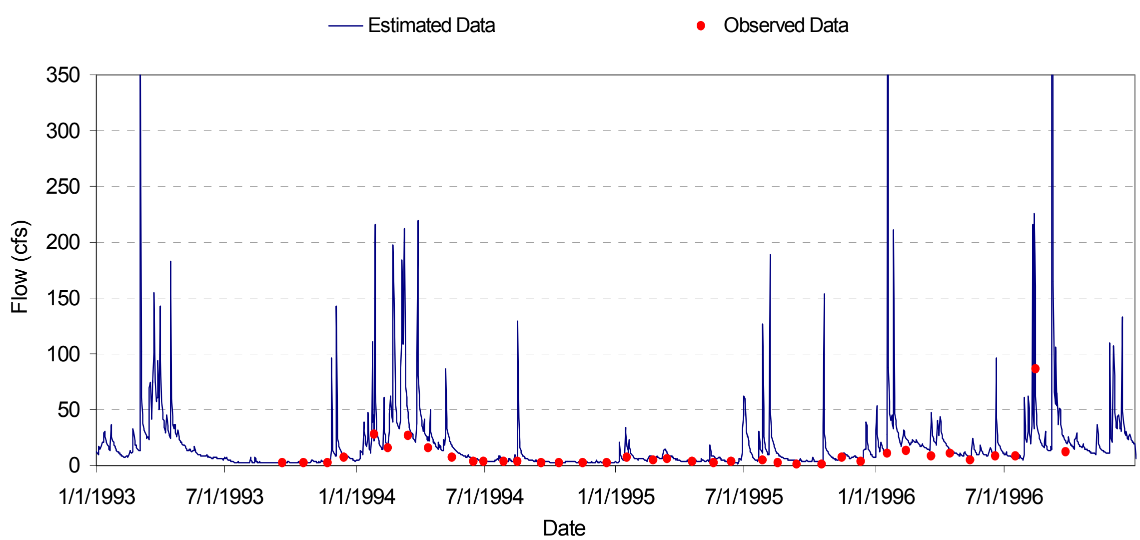

Figure 5.1 Comparison of Mill Creek observed flows to daily streamflow estimates for Mill Creek based on Linville Creek USGS gaging data

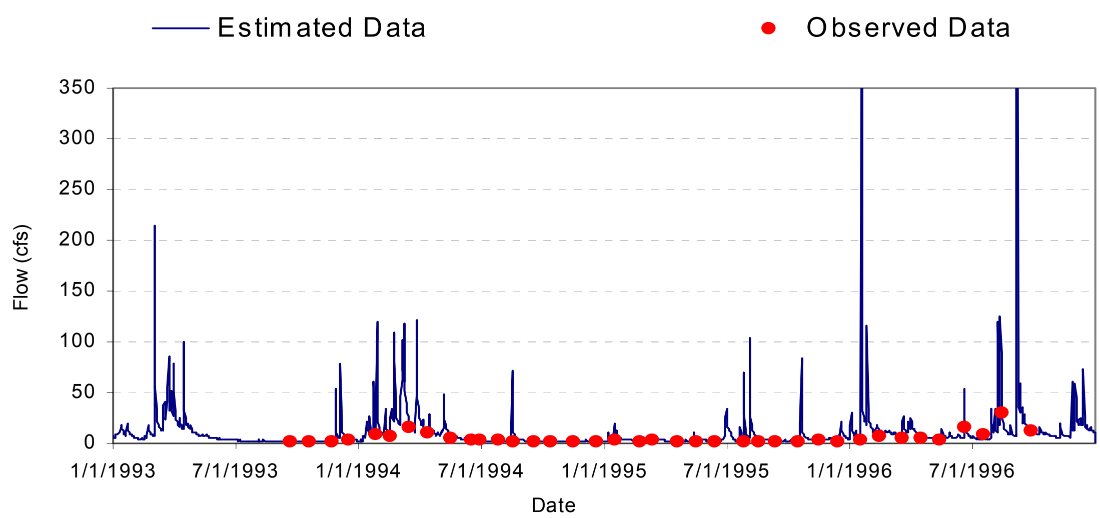

Figure 5.2 Comparison of Pleasant Run observed flows to daily streamflow estimates for Pleasant Run based on Linville Creek USGS gaging data

5.4 Explanation of Important Model Parameters

In the GWLF model, the nonpoint source load calculation is affected by terrain conditions, such as the amount of agricultural land, land slope, soil erodibility, farming practices used in the area, and by background concentrations of nutrients (nitrogen and phosphorus) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. Some of the more important parameters are summarized as follows:

Areal extent of different land use/cover categories: VADCR and MRLC land use coverages were used to calculate the area of each land use category in impaired and reference watersheds, respectively. Land use areas in the reference watershed (Hays Creek) were ground-truthed by VADCR and Tetra Tech personnel in March 2001 in order to verify that the MRLC land use coverage for Hays Creek was consistent with the VADCR land use coverages provided for the four impaired watersheds.

Curve number: This parameter determines the amount of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type and is calculated directly using digital land use and soils coverages. Soils data were obtained from Virginia county soil surveys and the State Soil Geographic (STATSGO) database for Virginia, as developed by the Natural Resources Conservation Services (NRCS).

K factor: This factor relates to inherent soil erodibility, and it affects the amount of soil erosion taking place on a given unit of land. The K factor and other Universal Soils Loss Equation (USLE) parameters were downloaded from the NRCS Natural Resources Inventory (NRI) database (1992).

Average values for specific crops/land uses in each watershed county were used (Rockingham and Shenendoah counties). The predominant crop grown in these watersheds is corn; therefore, cropland values were based on data collected in corn crops.

LS factor: This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

C factor: This factor is related to the amount of vegetative cover in an area. In agricultural areas, this factor is largely controlled by the crops grown and the cultivation practices used. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion.

P factor: This factor is directly related to the conservation practices used in agricultural areas. Values range from 0 to 1.0, with larger values indicating a lower potential for erosion.

Sediment delivery ratio: This parameter specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size.

Unsaturated available water-holding capacity: This parameter relates to the amount of water that can be stored in the soil and affects runoff and infiltration.

Dissolved nitrogen in runoff: This parameter varies according to land use/cover type. Reasonable values have been established in the literature. This rate, reported in milligrams per liter, can be readjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Dissolved phosphorus in runoff: Similar to nitrogen, the value for this parameter varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in milligrams per liter, can be readjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Nutrient concentrations in runoff over manured areas: These concentrations are user-specified concentrations for nitrogen and phosphorus that are assumed to be representative of surface water runoff leaving areas on which manure has been applied. As with the runoff rates described above, these concentrations are based on values obtained from the literature. They also can be adjusted based on local conditions such as rates of manure application or farm animal populations.

Nutrient buildup in nonurban areas: In GWLF, rates of buildup for both nitrogen and phosphorus have to be specified. These rates are estimated using published literature values and adjusted to local conditions.

Background nitrogen and phosphorus concentrations in groundwater: Subsurface concentrations of nutrients (primarily nitrogen and phosphorus) contribute to the nutrient loads in streams. Nutrient concentrations in groundwater were based on the results from a nationwide study of mean dissolved nutrients as measured in streamflow (as reported in Haith et al. 1992).

Background nitrogen and phosphorus concentrations in soil: Because soil erosion results in the transport of nutrient-laden sediment to nearby surface water bodies, reasonable estimates of background concentrations in soil must be provided. This information was based on literature values that were adjusted locally depending on manure loading rates and farm animal populations.

Other less important factors that can affect sediment and nutrient loads in a watershed also are included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF User's Manual (Haith et al. 1992). Pages 15 through 41 of the manual provide specific details that describe equations and typical parameter values used in the model.

5.5 Hydrology Calibration

Using the input files created in the BasinSim 1.0, GWLF predicted overall water balances in impaired and reference watersheds. For Mill Creek and Pleasant Run weather data obtained from the NCDC meteorological station located at Dale Enterprise were used to model the chosen time period (April 1, 1991 through March 31, 1998). As discussed in Section 5.3, the modeling period is determined based on the availability of weather and flow data that were collected during the same time period. Calibration statistics are presented in Table 5.3. In general, an R^2 value greater than 0.7 indicates a strong, positive correlation between simulated and observed data. These results indicate a good correlation between simulated and observed results for these watersheds. A total flow volume error percentage of less than 10 percent was achieved. Reference watershed results also indicate a good correlation between simulated and observed flow volumes. Hydrology calibration results and the modeled time period for reference watersheds are given in Figures 5.3 and 5.4. As discussed above, streamflow data used for Mill Creek and Pleasant Run simulations were based on flow data collected at a USGS gage located in a similar watershed. Kerrs Creek gaging data were used to calculate flow in Hays Creek. Differences between observed and modeled flows in these watersheds are, therefore, likely due to inherent errors in flow estimation procedures based on watershed size.

Table 5.3 GWLF flow calibration statistics

Modeled Watershed	Simulation Period	R2 (Correlation) Value	Total Volume % Error
Mill Creek (at the mouth)	4/1/92-3/31/98	0.78	1.04%
Pleasant Run (at the mouth)	4/1/91 - 3/31/98	0.90	0.6%
Hays Creek (at the VADEQ biostation)	4/1/90-3/31/97	0.79	0.1%

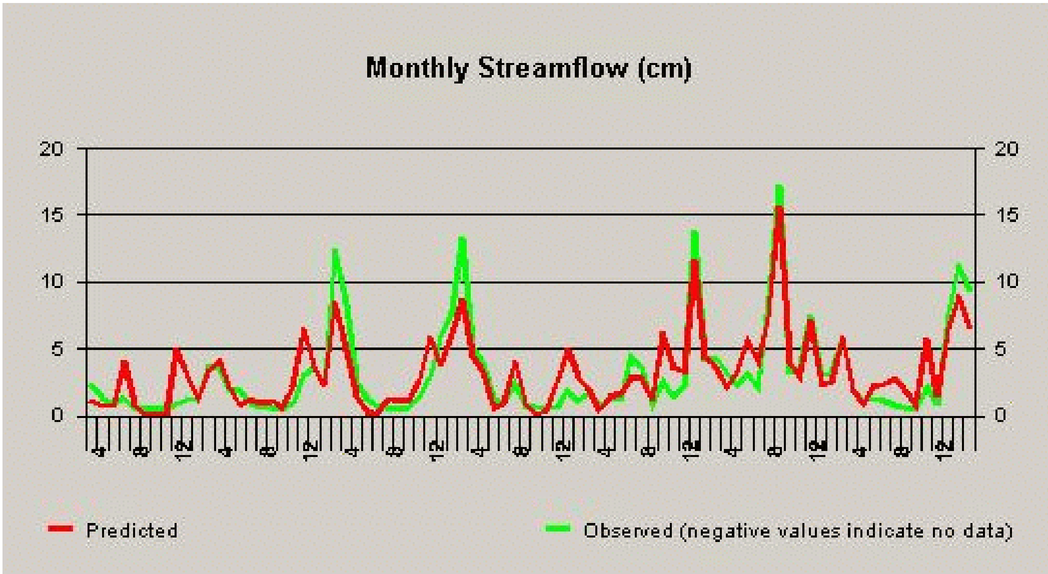

Figure 5.3 Hydrology calibration at the mouth of Mill Creek (4/1/91-3/31/98)

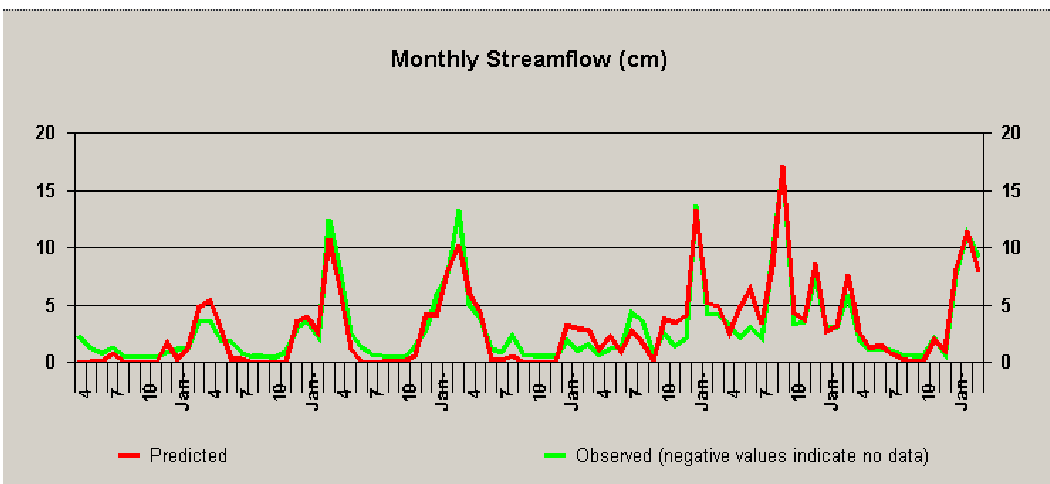

Figure 5.4 Hydrology calibration at the mouth of Pleasant Run (4/1/91-3/31/98)

SECTION 6

TMDL METHODOLOGY

6.1 TMDL Calculation

Impaired and reference watershed models were calibrated for hydrology using different modeling periods and weather input files. To establish baseline (reference watershed) loadings for sediment and phosphorus, the GWLF model for Hays Creek was run with the weather input file that was used for the impaired watershed simulations. This step was needed to standardize the modeling period (April 1, 1992 through March 31, 1998) and weather conditions (which affect pollutant loading rates) between impaired and reference watersheds for the calculation of TMDLs. In addition, the total area for the reference watershed was reduced to be equal to its paired target watershed, as discussed in Section 5.3. This was necessary because watershed size influences sediment delivery to the stream and other model variables.

The 6-year means for pollutants of concern were determined for each land use/source category in the Mill Creek and Pleasant Run watersheds. The first year of each model run was excluded from the pollutant load summaries because the GWLF model takes approximately one year to stabilize, therefore, the output is only presented for the years following the initialization year. The existing average annual sediment and phosphorus loads for Mill Creek and Pleasant Run are presented in Tables 6.1 and 6.2, respectively.

Transport loss estimates were used to determine the total sediment and phosphorus loads contributed by the three VPDES point sources in the Mill Creek watershed (* there are no point sources in the Pleasant Run watershed). The sediment delivery ratio calculated for the Mill Creek watershed (16.26%) was used to estimate sediment and phosphorus transport losses caused by deposition, removal, and other in-stream processes.

Table 6.1 Existing sediment and phosphorus loading in Mill Creek at the mouth

Source Category	Sediment Load (pounds per year)	Sediment % of Total	Phosphorus Load (pounds per year)	Phosphorus % of Total
Row Crops	7,394,392	65.2%	6,203	51.0%
Pasture/Hay	3,517,849	31.0%	2,811	23.1%
Forest	26,308	0.2%	18	0.1%
Urban (grouped pervious and impervious areas)	364,670	3.2%	1,758	14.5%
Transitional	42,270	0.4%	28	0.2%
Water	0	0.0%	0	0.0%
Groundwater	0	0.0%	782	6.4%
Point Sources (permitted load minus transport loss - 16.26%)	231(total)	0.002%	116 (total)	1.0%
Septic Systems	0	0.0%	438	3.6%
Total Existing Load	11,345,719	100%	12,155	100%

Table 6.2 Existing sediment and phosphorus loading in Pleasant Run at the mouth

Source Category	Sediment Load (pounds per year)	Sediment % of Total	Phosphorus Load (pounds per year)	Phosphorus % of Total
Row Crops	10,177,827	75.3%	6,809	65.4%
Pasture/Hay	2,482,016	18.4%	1,814	17.4%
Transitional/Barren	377,117	2.8%	235	2.3%
Forest	16,505	0.1%	11	0.1%
Water	0	0.0%	0	0.0%
Urban (grouped pervious & impervious areas)	457,657	3.4%	864	8.3%
Groundwater	0	0.0%	433	4.2%
Point Sources (none in the watershed)	0	0.0%	0	0.0%
Septic Systems	0	0.0%	239	2.3%
Total Existing Load	13,511,122	100%	10,404	100%

The TMDLs established for Mill Creek and Pleasant Run consist of a point source wasteload allocation (WLA), a nonpoint source load allocation (LA), and a margin of safety (MOS). The sediment and phosphorus TMDLs for Mill Creek and Pleasant Run were based on the total load calculated for the Hays Creek watershed (area adjusted to the appropriate watershed size).

The TMDL equation is as follows:
TMDL = WLA + LA + MOS

The WLA portion of this equation is the total loading assigned to point sources. The LA portion represents the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and the computational methodology used for the analysis. An explicit MOS of ten percent was used in TMDL calculations to provide an additional level of protection for designated uses.

TMDLs for Mill Creek and Pleasant Run were calculated by adding reference watershed loads for each pollutant together with point source loads to give the TMDL value (Table 6.3). Note that the sediment and phosphorus WLA values presented in the following tables represent the sum of all point source WLAs in each watershed, minus in-stream transport loss (as described on page 6-1).

Table 6.3 TMDLs for Mill Creek and Pleasant Run (at the mouth of each stream)

Watershed	Pollutant	TMDL (lbs/yr)	LA (lbs/yr)	WLA (lbs/yr)	MOS (lbs/yr)	Overall % Reduction
Mill Creek	Sediment	6,967,698	6,270,697	231(total) (WLA for each point source = 77)	696,770	45%
	Phosphorus	6,001	5,285	116 (total) (WLA for each point source = 38.7)	600	56%
Pleasant Run	Sediment	4,411,231	3,970,108	0	441,123	71%
	Phosphorus	3,910	3,519	0	391	66%

** Note that the overall % reduction is applied to the TMDL load exclusive of the MOS.*

6.2 Waste Load Allocation

Waste load allocations were assigned to each point source facility in the watersheds. Point sources were represented by their current permit conditions and no reductions were required in the TMDL. Current permit requirements are expected to result in attainment of the WLAs as required by the TMDL. Point source contributions even in terms of maximum flow are minimal, therefore, no reasonable potential exists for these facilities to have a negative impact on water quality and there is no reason to modify the existing permits. Note that the sediment WLA values presented in this section represent the sum of all point source WLAs in each watershed, minus in-stream transport loss (as described on page 6-1).

6.3 Load Allocation

Load allocations were assigned to each source category in the watersheds. Several load allocation scenarios were developed for each watershed and pollutant to examine the outcome of various load reduction combinations. The recommended scenarios for Mill Creek (Table 6.4) and Pleasant Run (Table 6.5) are based on maintaining the existing percent load contribution from each source category. Two additional scenarios for each watershed and pollutant are presented for comparison purposes (Tables 6.6 and 6.7). Load reductions from agricultural sources are minimized in the first alternative and reductions from urban lands are minimized in the second alternative. The recommended scenarios balance the reductions from agricultural and urban sources by maintaining existing watershed loading characteristics. In each scenario, loadings from certain source categories were allocated according to their existing loads. For instance, sediment and nutrient loads from forest lands represent the natural condition that would be expected to exist; therefore, the loading from forest lands was not reduced.

Table 6.4 Recommended sediment and phosphorus allocations for Mill Creek (at the mouth)

Source Category	Sediment Load Allocation (lbs/yr)	Sediment - % Reduction	Phosphorus Load Allocation (lbs/yr)	Phosphorus - % Reduction
Row Crops	4,066,916	45%	2,072	67%
Pasture/Hay	1,934,817	45%	1,124	60%
Transitional	12,765	70%	14	50%
Forest	26,308	0%	18	0%
Water	0	0%	0	0%
Urban (grouped pervious & impervious areas)	229,892	37%	1,055	40%
Groundwater	0	0%	782	0%
Point Sources (WLA) * Existing load minus transport loss (see footnote)	231 (total) (WLA for each point source = 77)	0%	116 (total) (WLA for each point source = 38.7)	0%
Septic Systems	0	0%	219	50%
TMDL Load (minus MOS)	6,270,928		5,401	

**Note:WLAs represent the existing permitted load from each facility minus the estimated sediment transport loss, as described on page 6-1. Therefore, the allocation load given for each point source facility is equal to the existing, permitted load (no reduction).*

Table 6.5 Recommended sediment and phosphorus allocations for Pleasant Run (at the mouth)

Source Category	Sediment Load Allocation (lbs/yr)	Sediment - % Reduction	Phosphorus Load Allocation (lbs/yr)	Phosphorus - % Reduction
Row Crops	3,007,955	70%	2,022	70%
Pasture/Hay	734,632	70%	542	70%
Barren	73,719	80%	47	80%
Forest	16,505	0%	11	0%
Water	0	0%	0	0%
Urban (grouped pervious & impervious areas)	137,297	70%	259	70%
Groundwater	0	0%	433	0%
Point Sources (WLA) (none in the watershed)	0	0%	0	0%
Septic Systems	0	0%	204	15%
TMDL Load (minus MOS)	3,970,108		3,519	

Table 6.6 Alternative sediment and phosphorus allocations for Mill Creek (at the mouth)

Source Category	Sediment		Phosphorus	
	Minimize Agricultural Reductions	Minimize Urban Reductions	Minimize Agricultural Reductions	Minimize Urban Reductions
Row Crops	44%	46%	57%	71%
Pasture/Hay	42%	45%	52%	69%
Transitional	90%	70%	80%	50%
Forest	0%	0%	0%	0%
Water	0%	0%	0%	0%
Urban (grouped pervious & impervious areas)	90%	10%	80%	10%
Groundwater	0%	0%	0%	0%
Point Sources (WLA)	0%	0%	0%	0%
Septic Systems	0%	0%	80%	50%

Table 6.7 Alternative sediment and phosphorus allocations for Pleasant Run (at the mouth)

Source Category	Sediment		Phosphorus	
	Minimize Agricultural Reductions	Minimize Urban Reductions	Minimize Agricultural Reductions	Minimize Urban Reductions
Row Crops	75%	78%	75%	80%
Pasture/Hay	50%	50%	50%	65%
Barren	80%	80%	75%	75%
Forest	0%	0%	0%	0%
Water	0%	0%	0%	0%
Urban (grouped pervious & impervious areas)	80%	10%	80%	10%
Groundwater	0%	0%	0%	0%
Point Sources (WLA)	0%	0%	0%	0%
Septic Systems	0%	0%	15%	15%

6.4 Consideration of Critical Conditions

The GWLF model is a continuous-simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads, based on the daily water balance accumulated to monthly values. Therefore, all flow conditions are taken into account for loading calculations. Because there is usually a significant lag time between the introduction of sediment and nutrients to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual conditions is protective of the waterbody.

6.5 Consideration of Seasonal Variations

The continuous-simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season and hours of daylight for each month. The model also considers the months of the year when manure is applied to the land. The combination of these model features accounts for seasonal variability.

SECTION 7

REASONABLE ASSURANCE AND IMPLEMENTATION

7.1 Reasonable Assurance

Sediment and phosphorus reductions in the TMDLs are allocated entirely to agricultural and urban sources in each watershed. Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of sediment reaching the streams can be made through the planting of riparian buffer zones, contour strips, and cover crops. These BMPs range in efficiency from 20% to 70% for sediment reduction. Implementation of BMPs aimed at sediment reduction will also assist in the reduction of phosphorus loading. Additional phosphorus reductions can be achieved through the installation of more effective animal waste management systems and stone ford cattle crossings. Other possibilities for attaining the desired reductions in phosphorus and sediment include stabilization of stream banks and stream fencing. Further "ground truthing" will be performed in order to assess existing BMPs, and to determine the most cost-effective and environmentally protective combination of future BMPs required for meeting the sediment and nutrient reductions outlined in this report.

7.2 Follow-Up Monitoring

The Department of Environmental Quality will maintain the existing monitoring stations in these watersheds in accordance with its ambient monitoring program. VADEQ and VADCR will continue to use data from these monitoring stations to evaluate improvements in the benthic communities and the effectiveness of the TMDL in attaining and maintaining water quality standards.

7.3 Regulatory Framework

This TMDL is the first step toward the expeditious attainment of water quality standards. The second step will be to develop a TMDL implementation plan, and the final step is to implement the TMDL until water quality standards are attained.

Section 303(d) of the Clean Water Act (CWA) and current EPA regulations do not require the development of implementation strategies. However, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQ MIRA) directs VADEQ in section 62.1-44.19.7 to "develop and implement a plan to achieve fully supporting status for impaired waters". The Act also establishes that the implementation plan shall include that date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated cost, benefits and environmental impact of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, time line, legal or regulatory controls, time required to attain water quality standards, monitoring plan and milestones for attaining water quality standards. Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of VADEQ, VADCR and other cooperating agencies.

Once developed, VADEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan, in accordance with the CWA's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ also submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

7.4 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. In response to the federal Clean Water Action Plan, Virginia developed a Unified Watershed Assessment that identifies watershed priorities. Watershed restoration activities, such as TMDL implementation, within these priority watersheds are eligible for Section 319 funding. Increases in Section 319 funding in future years will be targeted towards TMDL implementation and watershed restoration. Other funding sources for implementation include the USDA's CREP program, the state revolving loan program, and the VA Water Quality Improvement Fund.

7.5 TMDL Implementation

Implementation of best management practices (BMPs) in the watersheds will occur in stages. The benefit of staged implementation is that it provides a mechanism for developing public support and for evaluating the adequacy of the TMDL in achieving the water quality standard. Implementation of this TMDL will also contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. In 1987, the Commonwealth of Virginia joined its partners in the Chesapeake Bay Program in a commitment to reduce the flow of controllable nutrients to the Bay and its tributaries by 40 percent by the year 2000. To meet this commitment, the first Tributary Strategy, finalized in December of 1996, was developed for the Shenandoah and Potomac River Basins. That strategy has been implemented since passage of the Water Quality Improvement Act in 1997, leading to tens of millions of dollars worth of cost-share for the installation of point source and nonpoint source nutrient reduction projects across the basins. Since then, tributary-specific nutrient and sediment reduction goals and strategies – including implementation measures to achieve these goals by 2010 - were established. For the Shenandoah and Potomac River Basins, an Interim Nutrient Cap Strategy was published in March 2001. The Interim Nutrient Cap Strategy is intended to continue the coordinated effort, to maintain the level of nutrient reductions that have been achieved to date and to achieve the additional reductions needed to meet new environmental endpoints for the Chesapeake Bay. While the Interim Nutrient Cap Strategy contains both point and nonpoint source control mechanisms, the implementation of these sediment and phosphorus TMDLs will require only nonpoint source reductions. Therefore, Appendix A of this document includes Chapter V, Nonpoint Source Implementation Mechanisms, of the Strategy. The chapter contains reduction options in six major activity categories, which are 1) managing storm water runoff, 2) outreach and public education, 3) urban nutrient management, 4) on-site wastewater treatment, 5) agriculture, and 6) shoreline erosion and protection. For these TMDLs, all except the last category apply. The nutrient reduction options identified as part of the Interim Nutrient Cap Strategy can serve as useful guides in selecting and prioritizing measures to reduce sediment and phosphorus contribution to these streams.

7.6 Water Quality Standards

If implementation of reasonable BMPs has failed to improve or restore the benthic community and additional controls would have widespread social and economic impacts, VADEQ has the option of performing a Use Attainability Analysis (UAA) using the factors set forth in 40 CFR ' 131.10(g). A UAA is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and economic factors as described in the Federal Regulations. The primary factors to include are as follows: 1. the factor of widespread social and economic impacts 2. human caused conditions and sources of pollution prevent the attainment of the use and cannot be remedied. The stakeholders in the watershed, Virginia, and EPA will have an opportunity to comment on these special studies.

SECTION 8

PUBLIC PARTICIPATION

The first public meeting on the development of TMDLs for Mill Creek and Pleasant Run was held on May 2, 2002 from 7-10 p.m. at the DEQ Valley Regional Office located in the City of Harrisonburg. Public notice of the draft TMDLs and the public meeting was published in the Virginia Register on April 22, 2002 (Volume 18, Issue 16). Copies of the presentation materials were made available for public distribution at the meeting. The public comment period ended on June 3, 2002. Seven people attended the first public meeting. No written comments were received.

The second public meeting on the development of TMDLs for Mill Creek and Pleasant Run was held on July 23, 2002 from 7-10 p.m. at the DEQ Valley Regional Office located in the City of Harrisonburg. Public notice of the draft TMDLs and the public meeting was published in the Virginia Register on July 15, 2002 (Volume 18, Issue 22). Copies of the draft TMDL reports and presentation materials were made available for public distribution at the meeting. The public comment period ended on August 14, 2002. Eleven people attended the second public meeting. No written comments were received.

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APPENDIX A

EXCERPT FROM CHAPTER V OF THE INTERIM NUTRIENT CAP STRATEGY FOR THE SHENANDOAH / POTOMAC RIVER BASIN, COMMONWEALTH OF VIRGINIA, MARCH 2001

V. Nonpoint Source Implementation Mechanisms

As noted earlier, Virginia was able to meet the nonpoint source portion of the tributary strategy commitments. The strategy called for reducing nitrogen by 3,454,512 pounds and phosphorus by 561,441 pounds. As of December 31, 2000, Virginia had reduced nonpoint source nitrogen loads by 3.6 million pounds and phosphorus loads by 619,000 pounds. While these reductions surpassed the commitments set forth in the tributary strategy, they fall just short of a 40 percent reduction.

The nonpoint source 40 percent nitrogen goal is 4.1 million pounds leaving a nitrogen gap of approximately 500,000 pounds. The phosphorus reduction achieved is roughly 3,400 pounds short of the 624,400- pound reduction that would be needed to achieve a 40 percent phosphorus reduction from nonpoint sources. However, continuing the current rate of implementation should close this gap.

A. Maintaining the Cap for the Duration of the Interim Period

A significant portion of the nonpoint nutrient reduction in the original Shenandoah and Potomac Tributary Strategy came from agricultural BMPs implemented through the local soil and water conservation districts. Nutrient management plans also contributed a large part of the nutrient reduction goal. While important reductions must still be achieved through continuing and enhancing these practices, maintaining reductions in the face of increasing population and landscape changes will only be accomplished by shifting the emphasis to areas other than agriculture.

This interim Cap strategy will identify reduction options in six major activity categories. The general categories are managing storm-water runoff, outreach and public education, urban nutrient management, on-site wastewater treatment, agriculture and shoreline erosion and protection. The options are those mentioned in the public comment, focus group process.

The policies and practices proven instrumental to the success in meeting the original nutrient reduction goals must continue to be pursued and must be fortified with new policies and practices in order to meet the challenges presented by continued population growth and land use changes. The reduction categories are presented in an order reflection needs for new programmatic attention and development. The areas where the nonpoint source control experience is more limited are presented as the highest priority. Increasing nutrient loads must be reduced to maintain current levels. The recommendations are presented briefly in all six categories. Further discussions of each recommendation are presented in the sections that follow.

1. Recommendations
   a. Managing Stormwater Runoff
      - Expand the implementation of currently identified and accepted stormwater management and urban BMPs to all localities through the adoption of the Virginia Stormwater Management Regulations Water Quality Technology-based criteria on a jurisdiction wide basis.
      - Fully consistent local Erosion and Sediment Control Programs, Stormwater Control Programs and Chesapeake Bay Programs will need to be the standard for all communities.
      - Continue to investigate potential new BMPs and evaluate nutrient reduction and tracking information for incorporation into model.
      - Review the ESC and SWM Laws and Regulations for opportunities to clarify inspection, maintenance, and enforcement procedures, roles and responsibilities relating to the effective implementation of local and state programs.
      - Identify status and coverage of all existing SWM systems, what areas are treated to what level, where are gaps, (GIS database).
      - Develop a Better Site Design training program for county and municipal planners in the watershed using CBLAD's Better Site Design assessment document and workshops.
      - Develop model low impact development guidance and distribute to localities in the watershed.
      - Give localities that adopt low impact development ordinances priority consideration for all Water Quality Improvement funds or other state water quality related grants or loan programs.
      - Work with the Virginia Department of Economic Development to provide businesses located or relocating in the watershed financial incentives for incorporating better site design or low impact development principles in their facilities.

   b. Outreach and Public Education
      - Work to promote the understanding of individual responsibility and promote a conservation ethic
      - Initiate a paid multimedia campaign (television, radio, newspaper, etc.) in the major media markets in the watershed geared to urban, suburban, residential landowners
      - Seek partnerships with Washington, D.C., Maryland and the Chesapeake Bay Program for media purchases in the Washington, D.C. market
      - Develop a fulfillment component to the media campaign (toll-free hotline, fulfillment brochures, internet)
      - Enhance existing "hands on" opportunities to interact with landowners
      - Evaluate outreach affects and determine actual nutrient reductions

   c. Urban Nutrient Management
      - Develop and fully implement urban nutrient management program strategies to include:
         - nutrient management plans for golf courses, public and private lands

  - modification of state Nutrient Management Training and Certification program to include urban criteria
- Develop a framework for public and private land owners to use in a land maintenance contract which provides sample language to address nutrient management
- Promote and support of Virginia Cooperative Extension's Home Gardener Program
- Educate contractors on the safe use of deicers
- Investigate and encourage pelletizing biosolids into an acceptable consumer product
- Promote environmentally sensitive labeling for fertilizers and deicers
- Promote greater awareness among the general public as well as enforcement of pet waste regulations and maintenance

d. On-site Wastewater Treatment
- Promote and support citizen education programs currently being developed to raise awareness of karst and the appropriate use of BMPs in the vicinity of sinkholes and limestone outcrops
- Enhance homeowner education emphasizing the need for septic system inspection and pump-out. Also, increase awareness about materials that should not be put into any type of wastewater treatment system.
- Promote a local sponsor for the State Revolving Loan Fund for on-site systems
- Offer cost-share for repair or replacement of failing/malfunctioning systems

e. Agriculture
- Continue implementation of BMPs currently funded under the Virginia's Agricultural Cost Share Program.
- Continue Nutrient Management Program with both private and public certified planners
- Promote grazing land protection practices and manure management practices for horse industry
- Actively Promote the Conservation Reserve Enhancement Program
- Develop a program to maintain and/or replace agricultural BMPs to assure they continue to provide reductions.

f. Shoreline Erosion and Protection
- Initiate tracking of shoreline protection measures on the tidal Potomac and its major tributaries north of King George County.
- Establish a 50 percent cost-share program for properly designed and installed shoreline erosion control measures. Cost-share would be available for agricultural and residential landowners

2. Discussion

a. Managing Stormwater Runoff

The single most important problem and opportunity for nutrient reductions and water quality improvement is the effective management of stormwater and the design/construction of methods and facilities that effectively process or retain nutrients. Essential to this are programs for operation and maintenance that ensure these systems continue to function and do not create safety hazards or other concerns. A matter of increasing concern is the impact of highly urbanized areas.

The following are the most common BMPs utilized to manage stormwater runoff in urban areas and their respective phosphorus removal efficiencies outlined in the Virginia Stormwater Management Regulations (see table 7). Brief descriptions of these BMPs and the associated maintenance considerations can be found in the *Virginia Stormwater Management Handbook.*

Table 7. Target Removal Efficiencies of Typical Urban BMPs

Water Quality BMP	Target Phosphorus Removal Efficiency	Percent Impervious cover
Vegetated filter strip	10%	16-21%
Grassed Swale	15%	
Constructed wetlands	30%	22-37%
Extended detention (2 X WQ Vol)	35%	
Retention basin I (3 X WQ Vol)	40%	
Bioretention Basin	50%	38-66%
Bioretention filter	50%	
Enhanced extended detention	50%	
Retention Basin II (4 X WQ Vol)	50%	
Infiltration (1 X WQ Vol)	50%	
Sand filter	65%	67-100%
Infiltration (2 X WQ Vol)	65%	
Retention basin III (4 X WQ Vol w/ aquatic bench)	65%	

Source: Virginia Stormwater Management Regulations 4VAC3-20, effective March 1998

A combination of factors has resulted in increased interest of an even wider array of BMPs to serve the needs of the ultra-urban environment. Although there are a number of experimental and non-standard BMPs, the primary techniques currently under consideration can be found in Appendix D under the heading: “Green Rooftops”; “Manufactured Stormwater BMP Systems”; and “High Efficiency Street Sweeping.”

An important fact to understand when discussing the management of nonpoint source pollution within an urbanizing watershed is that even the most effective Best Management Practices (BMPs) controlling 100 percent of the landscape will still result in a net increase in pollutant load. This is compounded by the reality that in many cases there are physical limitations on utilizing the “best” BMP, meaning that less than ideal reductions are achieved.

Another fact is that may localities within the Shenandoah-Potomac watershed do not require any stormwater quality BMPs on new development since the adoption of a local comprehensive stormwater management program that is optional in most (lower populated) parts of Virginia. Tidewater, Virginia localities, defined as those localities that are located east of the fall line, are required to adopt a Chesapeake Bay Preservation Act (CBPA) ordinance. The CBPA ordinances require water quality BMPs in conjunction with the development of designated lands (based on soil, topography, and other physical features) within their jurisdiction. Any development outside of those designated lands typically occurs with no water quality provisions. Some localities, however, have chosen to designate their entire jurisdiction and therefore require stormwater BMPs on all new development. It should be noted that pollutant removal requirements in CBPA zones are based on meeting an average land cover condition. In some cases this allows a significant level of development before any stormwater BMPs are required. In contrast to this, localities within the Occoquan watershed in Northern Virginia are required to use BMPs to control nonpoint source pollution as a means of protecting the drinking water supply. Developers within the Occoquan watershed must meet a single post-development phosphorus removal requirement of up to 50 percent, regardless of average land cover condition. Appendix E contains an overview of the role of the CBPA in capping nutrients. This appendix also contains a discussion of how *better site design* and *low impact development* practices can reduce nutrient loading.

The effectiveness of state and local Erosion and Sediment Control (ESC) programs at reducing nutrient and sediment loads to the Shenandoah and Potomac rivers is limited by the effectiveness of the individual temporary ESC practices implemented on construction sites, and the ability of the local and state personnel to enforce the provisions of the Law and Regulations.

b. Outreach and Public Education
   (i) Overview

The success of the *1996 Shenandoah and Potomac River Basins Tributary Nutrient Reduction Strategy* is mostly the result of comprehensive cost-share funding for agricultural and forest lands and for wastewater treatment plant upgrades.

As previously stated, in order to maintain this current level of nonpoint source nutrient reductions, Virginia must go beyond agricultural BMPs. Greater reductions can be achieved through efforts to promote sound nutrient management practices on non-agricultural lands and greater emphasis on septic systems.

Currently there are 846,705 acres classified as urban or non-agricultural open lands. This is nearly 24 percent of the land base in the Shenandoah-Potomac watershed that have received minimal attention. Combined with nitrogen loads for septic systems, these lands are estimated to account for annual loads of 6,115,104 pounds nitrogen, 688,768 pounds phosphorus and 114,025 tons sediment.

Some reductions have been achieved from these lands and septic systems through demonstration projects and other localized initiatives funded through the special projects portion of the Water Quality Improvement Fund. However, they have not been dealt with in the same systematic way, as have agricultural and forested lands. Because of the practices necessary and the huge number of landowners involved, these lands do not lend themselves to the use of cost-share such as the one in place reaching farmers and other agricultural landowners

Dealing with these lands and the septic concerns in a comprehensive, systematic manner will require a strong public education and outreach component to reach the hundreds of thousands of landowners and land manager in the watersheds. Stakeholders have long called for such a campaign. However, for the first time we are hearing stakeholders express a need for this outreach campaign, even if it is funded by diverting funds from traditional “on-the-ground” practices.

The results of the local focus group meetings found a gap that exists in the information and education component that is a natural and indispensable part of watershed restoration. Focus groups in the Shenandoah Valley felt the educational campaign should be focused primarily on the urban, suburban landowner or manager. Focus groups in the Potomac felt while the focus should be on urban and suburban dwellers; the agricultural community could also benefit.

All agree that watershed stakeholders, on the whole, are not informed enough to be aware of their individual land-use effects on water quality. As many stakeholders are not aware of the alternatives available to them at little or no expense, an innovative public information concept is a necessary component to the adjustment of their mind-set, bringing them into the decision making process. This would make available information and offer concrete reasons for them to implement actions on their own land to improve quality of the water.

(ii) Elements of a Public Outreach and Education Program

An effective public education component of the Interim Nutrient Cap Strategy could include the following elements:

The commitment to fund a targeted mass media campaign including the purchase of print and radio/television advertising to run primarily in the Washington, D.C. media market. Maintaining nutrient reductions will require a change in the behavior and habits of residents in the watershed. This cannot be achieved without reaching them with repetitive messages on how to change and, more importantly, why the change will be beneficial to them. A comprehensive campaign employing television, radio, newspapers, mass transit signage and other tools will be necessary. Non-controversial messages featuring a mix of stewardship messages and tips on changing behavior would be featured.

This type of campaign has not been done before because of the cost involved. Purchasing media in the Washington, D.C. market is expensive. However, since this is not an exclusive Virginia market, the state should explore funding partnerships with Maryland, D.C., and the Chesapeake Bay Program Office. Because of the public service nature of the message, the state should also approach organizations such as state and regional broadcasters' associations, the National Advertising Council and Radio Advertising Bureau to develop partnership opportunities.

Exposing stakeholders to the message is only one part of the solution. In the past, Campaigns encouraging people to recycle have been cited as a leading reason in getting people to change their behavior to improve their environment. While repeatedly exposing lawmakers and citizens to recycling messages was key to this success, it didn't become a common practice until systems were put in place that made recycling easy.

Advertising alone can not provide information needed for people to act on a call to action. Appropriate programs must be designed and put into place to ensure proper implementation of the message. To provide more information to average citizens on how they can improve water quality, advertisements should reference a toll-free number. Callers would then receive an informational packet on ways they can positively impact water quality in their area.

A toll-free number already exists that could be used for this initiative (1-877-42-WATER). Funding would be needed to handle calls and fulfillment. New collateral materials may need to be developed. Agencies such as DCR, DEQ, and VCE already have pieces that may be incorporated into these packets, but larger quantities will need to be printed and disseminated.

An intensified "hands-on" approach should be adopted when interacting with landowners and managers.

Advertising followed by exposure to printed materials with concrete examples cited will assist those citizens who are environmentally concerned or otherwise presupposed to this kind of change. Our experience in working with the agricultural community in promoting cost-share, as well as case studies, of watershed initiatives nationally, show that the greatest and most efficient change of behavior takes place when mass media messages are accompanied with personal, one-on-one selling. This is certainly more problematic when trying to reach suburban residents rather than farmers. However, through Master Gardeners and other programs administered primarily by the Virginia Cooperative Extension, a network to reach this market segment does exist. These efforts should be intensified to complement the mass media campaign.

The public education component should continue, with outreach to schools as part of science and environmental studies, thereby reaching future stakeholders at all levels.

An evaluation mechanism should be implemented that can be used to attribute actual nutrient reductions to the public education component.

Cost has been one reason a paid mass media campaign has not been implemented previously as a nutrient reduction strategy. The other concern has been how to account for actual reductions. The use of the toll-free number and information gathered by Master Gardeners and VCE would give us a mechanism to do follow up surveys to see what level of behavior change has resulted.

A more expensive, but more comprehensive method would be to conduct a phone survey of a random sample of residents targeted areas of the watershed. This survey would determine if the campaign or other factors have led to a change in their use of fertilizers, ground covers maintenance of their septic system or other factors affecting water quality.

A mass media approach, with fulfillment and increased personal selling are needed if behavior changes are to take place in time to have them counted as reductions under the final interim nutrient cap strategy. This would enhance public motivations, an increase pride of ownership and involvement in the watershed, increasing the stakeholder base of support.

In the long run they also complement efforts by the Chesapeake Bay Program to introduce Bay related messages into the school curricula, provide an outdoor Bay or stream related experience or other intensified public outreach efforts to develop a conservation ethic over time.

(iii) Potential Costs

In purchasing advertising it is important to reach a certain threshold of number of people who are exposed to your message with frequency (number of times they are exposed). For a major market like the Northern Virginia region, a rough cost estimate for an effective campaign is approximately $500,000 to $1,000,000 annually.

c. Urban Nutrient Management

Nutrient pollution from the Potomac's rapidly urbanizing areas and "ultra urban" areas is becoming a greater concern. These concerns were voiced at all thirteen focus group meetings conducted while developing strategy. Many concerns about the lack of urban nutrient management were also voiced at the Potomac Forum held in August 2000, at George Mason University in Manassas, Virginia.

Current educational programs that specifically address urban nutrient management are limited. Some of these programs, which are administered by the Virginia Department of Conservation and Recreation and Virginia Cooperative Extension, educate the fertilizer industry and suppliers of lawn care services and homeowners on a one-on-one basis. These programs have shown success and need continued funding.

However, there is even greater need to expand urban nutrient management programs into other areas. These would include writing certified nutrient management plans for golf courses, local, state, and federal government lands, homeowner associations and office parks that would provide land maintenance contract guidelines that incorporate sound nutrient management practices.

Public and private turf landscape areas are increasing in the Shenandoah-Potomac watershed. Public lands are school grounds, athletic fields, playgrounds, parks, municipal government offices, roadsides, federal properties, as well as some hospitals and cemeteries. These entities need nutrient management plans or land maintenance contracts that address nutrient management issues. Private turf and landscape areas typically include office parks, shopping malls, houses of worship, businesses, and common areas of large subdivisions. Many of these areas have extensive turf areas that need to be maintained, often with a high expectation for a lush, green appearance. Nutrients applied by private land managers are largely unknown and unregulated. Both public and private land managers would benefit from regular educational opportunities concerning proper fertilizer selection, timing, and application. Addressing these areas offers an attractive way to put nutrient management conservation practices on a significant amount of urban acreage effectively and efficiently with a voluntary program.

Golf courses are an increasingly common landscape feature. Management strategies to protect water quality with this land use should be directed at water runoff or ground water infiltration from intensely managed turf areas like fairways, tees, and greens. Appropriate Nutrient Management strategies need to be developed for golf courses. Both private and public certified nutrient management specialists should be able to write certified nutrient management plans. Furthermore, the current, Nutrient Management Training and Certification program is heavily weighted towards knowledge in the agricultural sector. Appropriate changes to the Certification process of private planners to address urban nutrient management are needed. Research and demonstration efforts to increase the number of management tools to more appropriately apply nutrients to golf courses are needed.

Managed lawns are a common feature in urban and suburban areas of the Shenandoah-Potomac watershed. According to the 1998 Virginia Agricultural Statistics, Virginia has some 714,000 acres of home lawns, with more acres expected. Due to the large number of individuals involved in the care of home lawns, a successful nutrient management strategy should proactively address lawn care awareness among the general public. Free educational opportunities for interested homeowners to learn correct and unbiased methods and practices related to lawn fertilizer selection, timing, and application should also be provided. Some work in this area is already being provided with Water Quality Improvement Act grand funds through local Virginia Cooperative Extension offices.

Deicing materials that contain ammonium nitrate and urea are commonly used on public and commercial road and parking lots. These materials represent a potentially significant nitrogen load to receiving waters during snowstorms. Alternative deicers such as granular and liquid calcium chloride exist, but storage facilities for these materials would need to be developed to allow for bulk purchase and use. Educational programs could be developed to educate contractors on the safe use of deicers. Furthermore, labeling laws could be instituted to prevent deicers sold across the counter to contain nitrogen or phosphorus products.

Biosolids, the product of sewage treatment plants, present many nutrient management opportunities. Pelletizing the biosolids into an acceptable consumer product would remedy negative public perception concerning odor with regular biosolid applications. Pelletized Class A biosolids are not currently regulated, can be sold and shipped as commercial fertilizer, and generally have fewer public perception problems than the regulated biosolids. Nutrient management practices should be used to help develop marking opportunities for the biosolids to offset treatment costs to municipalities and ensure safe use at the land application site. Phosphorus based nutrient management and the expanding poultry industry will make pelletized biosolids compete for a finite amount of agricultural land that needs to receive supplemental nutrients. However, there appears to be some opportunity for pelletized biosolids to compete with commercial phosphorus fertilizer products, such as diammonium and monoammonium phosphate, that are currently be used.

Improperly disposed pet waste is a potential source of nutrients as well as fecal coliform bacteria. Greater awareness among the general public, as well as enforcement of existing regulations is recommended.

d. <u>On-site Wastewater Treatment</u>

There is strong concern across the Shenandoah-Potomac basin for pollution attributable to failing or malfunctioning septic systems. Several streams in the watershed are listed as impaired and are thought to be impacted by wastewater. Communities along these streams expanded or were developed from about the 1930s through 1970s. Malfunctioning on-site wastewater treatment is likely a major source of bacteria and nutrient contamination in the streams. Leaking septic tanks or pipes may also be a source of nutrients transported to waters underground or in streams.

Much of the developed area in the Shenandoah River watershed is underlain by carbonate rock. Fractures and dissolution channels occur frequently in the folded limestone and shale of the valley. There are numerous sinkholes and limestone outcrops. Soil depth may be shallow over shale, and soil depth in areas of limestone outcrops is very irregular. These conditions allow a direct flow-path underground for surface runoff or wastewater discharge. The resulting of surface water with water underground plays a major role in the transport of nutrients to streams. During periods of no precipitation, the contaminated water underground provides base-flow (via springs) to streams, and possibly sustains elevated nutrient concentration in the streams.

Focus group participants identified three conditions on which to concentrate. (1) Maintenance and inspections of the small wastewater treatment systems (discharging less that 0.5 million gpd). (2) Maintenance and long-term needs of on-site wastewater treatment (septic) systems. (3) Malfunctioning septic systems in areas of karst, where there is greater risk of groundwater contamination via dissolution channels and fractures in carbonate bedrock. Suggested strategies to address these issues were (1) homeowner education programs emphasizing the need for septic system inspection and pump-out. (2) A local sponsor for the State Revolving Loan Fund for on-site system installation, and (3) cost-share for repair or replacement of failing/malfunction systems.

A homeowner outreach/education program to increase proper maintenance of septic systems would have strong benefits for nutrient cap maintenance. While septic system pump-out does not reduce release of nutrients, the properly maintain systems last longer and have better pathogen reduction. Pump-outs prevent potential clogging of the drainfield, therefore preventing drainfield failure that would result in potential nutrient runoff.

Other suggestions favored creation of a grant or loan program for the county to manage a program aimed at inspection and maintenance of septic systems/alternative systems, an the creation of ordinances to ensure sufficient land for drainfields and repair areas on newly subdivided parcels. Also suggested was making septic system siting requirements regionally specific, thereby taking into account soil variations throughout Virginia.

Additionally, the use of alternative on-site treatment systems for clusters of residences has potential to alleviate problems where several septic systems have failed. Consideration should be given to making grant funds available for installation of a cluster wastewater system infrastructure that offers wastewater services under a management program to a group of 3 to 100 homes per cluster. Local government must have the lead for operating such a system and charging a “sewer” fee to users as is done for large centralized systems. One possible objective for use of funds on wastewater projects should be to treat wastewater and adequately disperse the effluent into the environment, rather than for the collection of raw sewage and moving it around in miles of sewer infrastructure.

e. Agriculture

Maintaining the nutrient reductions achieved through the *Shenandoah and Potomac River Basin Tributary Nutrient Reduction Strategy* will require Virginia to maintain current programs as well as consider and adopt innovative implementation strategies for agricultural BMP implementation. It is necessary to target and promote additional implementation activities that will maintain nutrient reduction goals.

The successes of the Shenandoah and Potomac Tributary Strategy Implementation Project were a direct result of the adequate levels of funding for agricultural BMPs through the Water Quality Improvement Act. Watershed stakeholders have emphasized that funding will be the key to a successful Interim Nutrient Cap Strategy. Cost-sharing and other incentive-based programs have a proven track record of getting conservation on the ground. It is necessary to continue with adequate levels of funding for current nutrient reduction activities such as agricultural nutrient management and BMP cost-sharing, as well as new implementation activities. Without adequate funding to continue on-going activities it will be difficult to maintain current reduction levels.

A significant portion of the nonpoint nutrient reduction in the original Shenandoah and Potomac Tributary Strategy came from agricultural BMPs implemented through the local soil and water conservation districts. In order to effectively promote and implement the BMPs, local soil and water conservation districts need to have staff resources to provide technical assistance to landowners in the watershed. Nutrient management plans also contributed to a large part of the nutrient reduction goal. Nutrient Management planning, as well as many of the agricultural BMPs, is the most cost-effective method of achieving nutrient reductions.

The following Best Management Practices are offered through Virginia's Agricultural Best Management Practices Program. Continued funding and promotion of the practices remains critical to a successful Cap Strategy.

Table 8 Menu of Agricultural Best Management Practices

Best Management Practices	
BMP Treatment	**Units**
Conservation Tillage	acres
Farm Plans	acres
Nutrient Management	acres
Highly Erodible Land Retirement	acres
Grazing Land Protection	acres
Steam Fencing (Livestock from Streams)	ln. ft.
Cover Crops	acres
Grass Filter Strips	acres
Woodland Buffer Area (including CREP)	acres
Animal Waste Control Facilities	systems

Additional nutrient reduction activities exist in the agricultural sector. These include the targeting of the horse industry by promoting grazing land protection practices and manure management practices.

Nutrient management planning has targeted both the poultry industry and the dairy industry. The poultry industry is well established in the Shenandoah portion of the watershed. Current regulations require most poultry operations to develop a phosphorus based nutrient management plan. Any plan written after October 1, 2001, for a poultry grower must be a phosphorus based nutrient management plan. This represents a significant workload for public and private nutrient management planners. To comply with state regulations, these operations will be required to have an updated plan written every 3-5 years which facilitates the process of establishing a nutrient Cap on poultry litter produced in the basin.

Changes in poultry litter market conditions have resulted in additional poultry litter from outside the watershed being transported into the Shenandoah-Potomac watershed. Additionally, the continued encouragement of certain feed additives such as phytase, which reduces phosphorus in poultry manures. In addition, many beef producers are using poultry litter from the Shenandoah basin as fertilizer. Appropriate nutrient management practices need to be more widely promoted on these beef cattle farms to ensure that poultry litter is being applied at proper rates and current nutrient reduction gains are not eroded.

The dairy industry, estimated to be about 45,000 cows in the Shenandoah-Potomac basin, is a significant portion of the basin's agricultural base. Although the majority of these farms have current nutrient management plans, there are still a number without a plan. Continued targeting of the dairy industry is necessary in order to plan those remaining farms.

Additional activities outside of traditional government sponsored programs are also necessary to achieve additional reductions. Public grant funds, loans, and incentives are needed in order for the private sector to develop and implement projects resulting in new reductions. However, a significant number of basin stockholders have pointed to the urban and suburban communities for providing additional nutrient reductions.

f. <u>Shoreline Erosion and Protection</u>

[Not Applicable for Mill Creek, Pleasant Run, Muddy Creek, and Holmans Creek]

Note: The full nutrient cap document is available at http:/www.deq.state.va.us/pdf/strategies/nutrientcap.pdf